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Fr. Secchi and Stellar Spectra*

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When the history of the early days of astrophysics, astronomy's newest science, is written, one name which will figure prominently in its pages will be that of Father Angelo Secchi of the Society of Jesus, who for nineteen years directed the Observatory attached to the Roman College. Perhaps, we can anticipate this portion of what should prove a most fascinating story by discussing here the work done by Fr. Secchi in the description and classification of stellar spectra.

It is interesting to note that Fr. Secchi was stationed at Georgetown College, Washington, D. C., exactly one hundred years ago. His stay there was a very brief one, however, extending from November 19, 1848, to September 21, 1849, when he returned to Italy to assume the directorship of the Observatory of the Roman College, a position left open by the death of Fr. de Vico, S.J. Strangely enough, Fr. Secchi's work at Georgetown was not chiefly astronomy but electricity; indeed, the only paper we have representing the fruits of his studies there is a publication, written for the Smithsonian Institution, entitled: *Electrical Rheometry*.

Before we describe his classification of spectral types, we shall sketch briefly some of the outstanding details of his life and works. Angelo Secchi was born at Reggio in Emelia, Italy, on June 18, 1818, the son of a middle class joiner, Antonio Secchi. After studying for several years in the secondary schools of Reggio, Angelo entered the Society of Jesus at the age of sixteen. He made his spiritual, humanistic, and philosophical studies at Rome, after which he spent two years at the Roman College and three more in the college at Loreto, where he was professor of physics. In 1844, he returned to Rome where he began his theological studies and where he was ordained to the priesthood on September 12, 1847. The following year, Fr. Secchi, together with his fellow Jesuits, was forced to leave Italy because of the outbreak of the Roman Revolution. The exiles moved first to England, then on to America, Fr. Secchi settling at Georgetown. Here he made the acquaintance of F. M. Maury, the noted meteorologist and astronomer. This acquaintance developed into a lifelong friendship between the two scientists. However, Fr. Secchi's stay in America was shortened by the suppression of the revolution by the French and, more immediately, by the pressing need of the Roman College for a professor of physics.

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For the next twenty-nine years of his life, Fr. Secchi lived in Rome, where his scientific labors, though often threatened by political outbreaks such as the Piedmontese Invasion of 1870, were interrupted only by his death on February 26, 1878.

Fr. Secchi's works in astronomy cover the whole range of the astrophysics of his day. He specialized in solar problems, as his many articles on sunspots and solar prominences show most clearly. He was also well known for his revision of Struve's Catalogue of Double Stars, and for his photographs taken at the time of total eclipse of the sun. Besides his astronomical researches, Fr. Secchi found time to be an active meteorologist inventing the Meteorograph, (Figure 1), an instrument which recorded automatically variations in atmospheric pressure, temperature, wind velocity, and relative humidity. In addition to this, Fr. Secchi could employ his wide knowledge and skill as a physicist in his geodetic measurements and in his theoretical investigations of the relations among the different kinds of physical forces.

The better to evaluate Fr. Secchi's contributions to Stellar Spectroscopy, we must evaluate his work in relation to those who preceded him. Thus our topic divides itself naturally into two branches:

1. The influence of previous researches on the work of Fr. Secchi.
2. The evolution of Fr. Secchi's system of classification of stellar spectra.

Every man in his scientific work is influenced in manifold ways by the successes and failures of those who have preceded him and there is no one in all the vast halls of science who does not come soon to understand, (as Newton once wrote and as St. Bernard had written before him) that if we see farther than others it is because we have been standing on the shoulders of giants. Now to this maxim, Fr. Secchi would humbly and readily subscribe. Who then were his giants and how far had they seen?

Joseph von Fraunhofer was the first and the greatest of these giants. Though he was interested in the many phenomena which he discovered chiefly as means of perfecting his optical instruments, still his scientific disposition was such that he described and recorded in detail every observation he made. In 1817, Fraunhofer modified the instrument he had employed in mapping the solar spectrum and adapted it to the study of the much fainter light of the fixed stars. His first instrument consisted of a 60° prism of flint glass, a cylindrical lens, and a theodolite objective. Later he reduced the size of the prism to 37° 40′. With this apparatus he made the initial spectral studies[1] of several first magnitude stars, the results of which we may summarize as follows:

1. Spectra of the stars differ from the solar spectrum, whereas the moon and planets show a marked resemblance to the sun's spectrum.
2. Further, the stellar spectra differ widely among themselves; Sirius shows broad bands in the blue region of the spectrum; Capella

[1] *Edinburgh Phil. Journal*, **9**, 1823, and *Edinburgh Journal of Science*, **7**, 1827.

shows a spectrum in which the same fixed lines appear at 'D' and 'b' as in sunlight; the spectrum of Betelguese contains numerous fixed lines.

It was through these researches that Fraunhofer, the instrument maker, succeeded in proving that the lines seen in the spectroscope were not

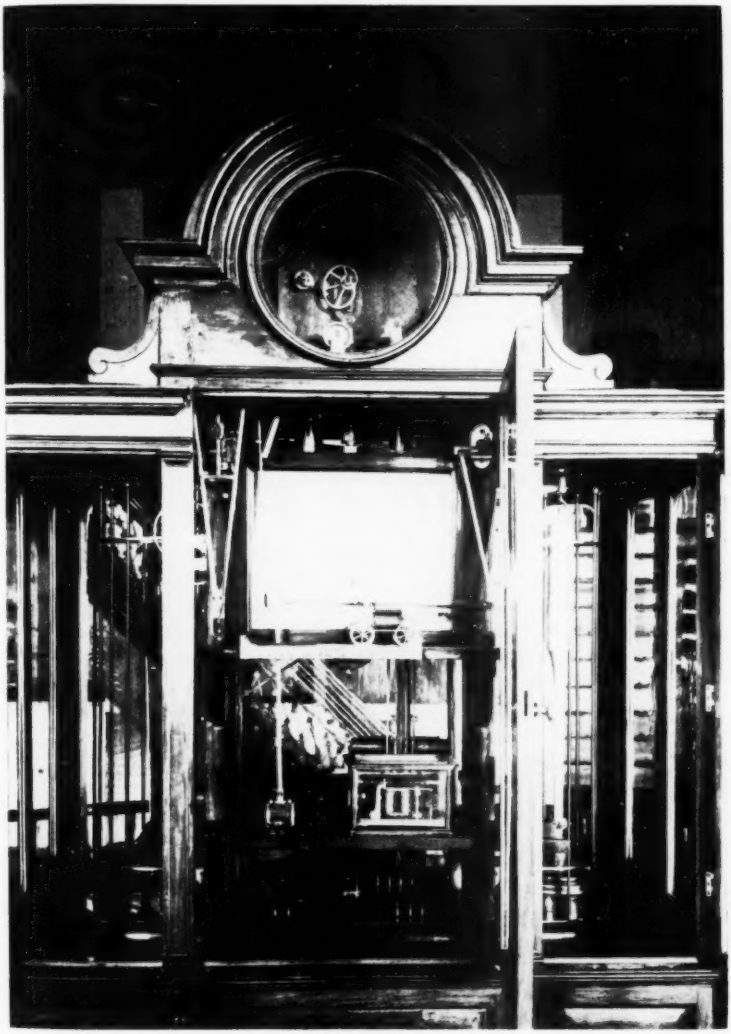

FIGURE 1

Meteorograph built by Fr. Secchi for the Manila Observatory. This famous instrument was destroyed in the Battle for Manila at the close of World War II.

purely telluric, a question which was being debated rather heatedly at that time. In addition, Fraunhofer, the astrophysicist, pointed out the similarities and differences among the stars and hinted broadly at the classifications of the hydrogen stars, the yellow solar type stars, and the red stars. Three years after the completion of these researches of 1823, Joseph von Fraunhofer died, and, though his work was repeated by Lamont, it could not be extended because of some defect in the optical system.

In 1855, Fr. Secchi at Rome made his entry into the field of stellar spectroscopy. It was a brief entrance, however, and it was not until seven years later that he was able to devote his labors to this field. As he himself writes:

> In 1855, with a theodolite fitted up with a prism we repeated Fraunhofer's observations; a little prism adapted to the great Merz Refractor furnished us with such a beautiful spectrum of Sirius that it made us eager to continue such researches; but other occupations kept us busy.[2]

The next after Fraunhofer to offer giant's shoulders to Fr. Secchi and to all subsequent astrophysicists was Kirchoff, who in 1860 enunciated the fundamental laws of Spectrum Analysis when he published his monumental chemical interpretation of the Fraunhofer lines. In this work, Kirchoff explained the presence of the familiar metals as glowing gases in the sun's atmosphere. This announcement occasioned a renewal of interest in the spectrum analysis of the stars and that interest, which had lagged since the days of Fraunhofer, quickened almost simultaneously in Italy, in England, and in America.

That very year, Giovanni Battista Donati[3] of Florence began his observations, the results of which he published in 1862. The chief feature of Donati's classification was his separation of the various stars according to their colors. Thus he classified Sirius, Vega, Procyon, Fomalhaut, and Rigel as white stars, Altair and Capella as yellow stars, Arcturus and Pollux as orange stars, and Aldebaran, Betelgeuse, and Antares as red stars. From his observations it became clear that the stellar lines bore a close relation to the color of the stars.

The next to undertake the problem of classifying the stars according to their spectra was Professor L. M. Rutherfurd after whom the Observatory at Columbia University is named. Professor Rutherfurd began his work of spectral classification in 1861 and published[4] his results on December 2, 1862, the same year in which Fr. Secchi resumed with new instruments his experiments of 1855, and one year before Fr. Secchi published his first results. As in many other instances in the history of science, so here we behold the claims of two parties to the same distinction. Of this we shall speak briefly later; in any case there is glory enough for all. Rutherfurd[5] seems to have been the first

[2] Secchi, Fr. A., "Le Soleil," Vol. II, p. 443.
[3] *M. N.*, **23**, 100, 1863.
[4] *American Journal of Science and Arts*, **35**, p. 77, 1863.
[5] *Ibid.*, p. 407.

to introduce a comparison spectrum into the field of view during the observation of a star. We may summarize his classification as follows:

> 1. The reddish or golden stars, which have many lines and most nearly resemble the sun. These include Capella, β Geminorum, α Orionis, Aldebaran, γ Leonis, Arcturus, and Procyon.
> 2. The white stars, which present spectra wholly unlike that of the sun. Sirius is the typical star of this group.
> 3. The stars which are also white but show no lines. Stars of this group include α Virginis and Rigel.

Here we see that Professor Rutherfurd hints at the division of white stars into the helium (O and B class) stars and the hydrogen (A class) stars. He misses the distinction between solar and banded spectra and also the subdivision of the banded spectra into the K and M stars and the R, S, and N stars. Fr. Secchi, on the other hand, will fumble somewhat with the distinction of the different kinds of white stars, and be very nearly correct in his distinction of the later type stars.

Fr. Secchi appears to deny our American spectroscopist the credit he deserves. This is shown in a quotation from his work, "Le Soleil," in which he writes:

> Some have attributed the discovery of types to M. Rutherfurd, but even if this scholar had recognized independently the diversity of spectra, something which had already been accomplished by Fraunhofer, still he did not establish these types according to characteristics proper to their spectra, but only according to their natural colors, which is something quite different. Further, in order to establish these types, that is to make clear that all stars are reducible to these types, it is necessary to make a complete survey of the stars and this M. Rutherfurd has not done, but this has been done by us.[6]

This criticism seems to me to be quite unfair to Professor Rutherfurd, who actually did establish the types according to their spectral characteristics and not merely according to their colors. Further, Rutherford seems (intentionally or not) to have indicated the true temperature sequence, something which Fr. Secchi, though he paved the way for it, never fully achieved.

Now, we must not be misled into thinking that Fr. Secchi imagined himself to be the very first person to do effective research in this field. No, he was well aware of the fact that he stood on giants' shoulders and he expresses this awareness in the *Chemical News* for October 9, 1868, when he says:

> Several astronomers followed Fraunhofer and Donati, among whom was the celebrated Mr. Huggins to whom we owe the description of a great number of spectra, and also the application of the principle of determining the substances present in a star from the black absorption lines which we see in its spectrum. Mr. Huggins also made the wonderful discovery of the gaseous state of the nebulae. The field opened by these astronomers was immense and I tried to glean some ears in it.[7]

Sir William Huggins and his wife and his co-worker, Mr. Miller, carried on their works contemporaneously with Fr. Secchi. It seems

[6] "Le Soleil," Vol. II, pp. 444-445.
[7] *Chemical News*, Vol. XVIII, p. 18, 1868.

quite clear that we can in no wise attempt any kind of fitting evaluation of Huggins' classic works. We must be content here to summarize that work in relation to that of Fr. Secchi in the words of Russell, Dugan, and Stewart, who have commented fittingly:

> Huggins studied a few stars carefully and identified lines of sodium, magnesium, calcium, iron, hydrogen, etc.; Secchi examined a great number of stars, nearly 4000 in less detail and with a view to their classification.[8]

Still another Englishman was at work about this time on the multifaceted problems of stellar spectra. He was Mr. J. Carpenter of Greenwich, who published[9] his observations of the spectra of 19 stars in April, 1863, just three months before Fr. Secchi's first classifications appeared. In fact, Carpenter's scheme is quite similar to the Secchi classification, for he places in one group the red stars, which showed broad bands, in another, the white stars, featured by the hydrogen lines, and in the third, the solar stars, where the metallic lines are especially prominent.

Having seen something of Fr. Secchi's astrophysical forebears and contemporaries, we come now to consider the spectral classifications of Fr. Secchi himself.

For clarity, we shall consider first the instruments he employed, then the five different classifications made during the years from 1863 to 1868, and finally some of the prominent features and interesting by-products of these classifications.

In his researches, Fr. Secchi was aided immensely by improvements in instrument making, not the least of which was the invention of the direct vision prism by Amici, and its employment in a new compact spectroscope by Hoffman, Janssen, and Amici. In May, 1862, Fr. Secchi ordered one of these instruments from Hoffman and it arrived the following December. In the meantime, as Fr. Secchi tells us in describing his first spectroscope:

> While we were awaiting this instrument, M. Janssen brought a small spectroscope to Rome; we applied this to the large Merz Refractor, and thus made our early researches in which we detected sodium in Betelgeuse.[10]

The second spectroscope (Figures 2a, 2b, 2c) used by Fr. Secchi is the one ordered from Hoffman and with this he did all his work from 1863 to 1866. He found[11] that this instrument gave much more light than one with a slit, and further, that when comparisons with metallic or gaseous spectra were required, this spectroscope could be employed with a slit which was placed exactly in the focal plane of the cylindrical lens. However, this instrument absorbed a great deal of light and so

[8] Russell, Dugan, and Stewart, "Astronomy," Vol. II, p. 601.
[9] *M. N.*, **23**, p. 190.
[10] "Le Soleil," Vol. II, p. 443.
[11] *Ibid.*, p. 427.

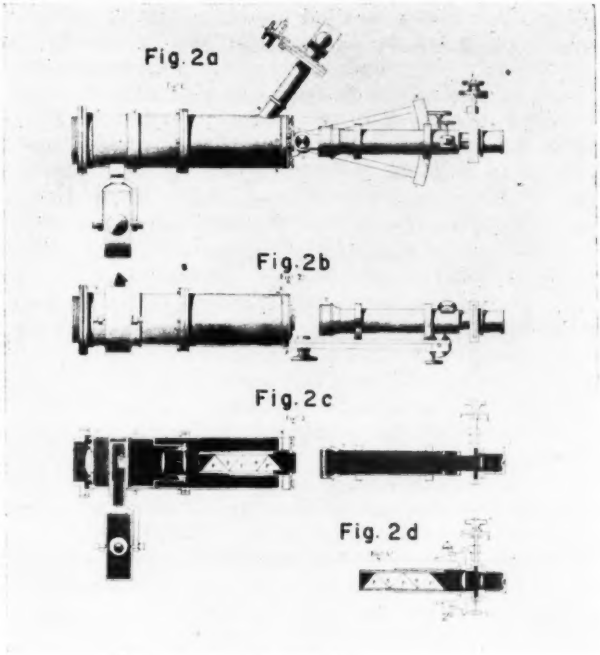

FIGURE 2
Secchi's Composite Spectroscope: Top View (Fig. 2a); Side View (Fig. 2b); Cross-sectional View (Fig. 2c); Secchi's Simplified Spectroscope (Fig. 2d).

Fr. Secchi began to look around for "a different arrangement which would overcome this difficulty."

This different arrangement became Fr. Secchi's third spectroscope (Figure 2d). It was a small, much simplified instrument fitted with a special ocular. Now, this latter consisted of two cylindrical lenses which allowed a maximum of light transmission. By changing the distance of the ocular, the linear dispersion of the prism could be changed. Fr. Secchi commented as follows on this instrument:

> Its feature was a remarkable conservation of light intensity. In connection with the telescope of 25 cm aperture (the Merz Refractor), we were able to obtain measurable spectra of stars of the seventh and even of the eighth magnitude.[12]

The fourth instrument[13] used by Fr. Secchi was what is known today as the objective prism or slitless spectroscope. As we saw before, Fraunhofer had used such an instrument with prisms of 60° and 38°. Fr. Secchi's great improvement consisted in introducing a prism of only

[12] "Le Soleil," Vol. II, p. 447.
[13] *Loc. cit.*

12°, whose chief feature was the relatively large dispersion which it afforded. Here, in fact, lay its weakness; for, in connection with the large refractor, the dispersion was too great for the observation of faint stars. Still, when mounted on a smaller telescope, this prism yielded very excellent spectra. A further feature of this apparatus was the addition of a small auxiliary "finding" telescope, which was attached by Fr. Secchi to the larger instrument. This auxiliary telescope was so mounted that the same star would be found in the field of the large telescope as was seen in the center of the field of the search telescope.

Such then were the instruments employed by Fr. Secchi in his investigations of stellar spectra. He tells us that most of his work was done with the ocular spectroscope (the third of the instruments described above). Before passing on to an examination of the researches made by Fr. Secchi with these instruments, we should reflect that all of these were visual spectroscopes and not spectrographs. For as far as we have been able to learn, Fr. Secchi, though he later came to be among the first to photograph the phenomena associated with a total solar eclipse, never applied photography to his studies of stellar spectra. It is worthy of note that Sir William Huggins did employ photography in his work, and we still have records of these earliest of spectrograms. A realization of the fact that Fr. Secchi did all of his work visually will doubtless explain why he perceived series of bands in the late-type stars as "kinds of rows of columns." This also increases our admiration for those keen powers of observation and recall which are demonstrated in his drawings of the spectra of different type stars. (Figure 3).

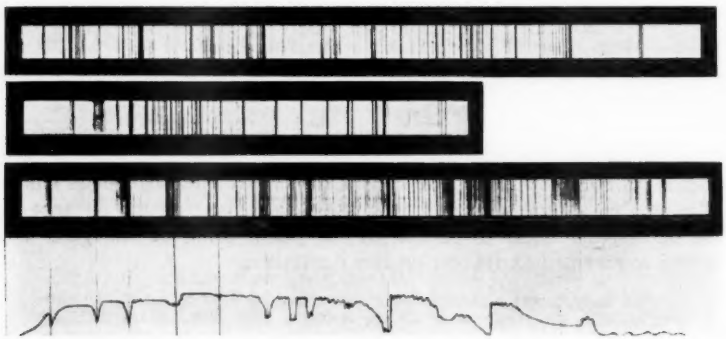

FIGURE 3

Spectrum of α Orionis (Top); α Tauri (Middle); α Scorpii (Bottom). Graph at bottom is Secchi's curve for the variation of light intensity in the spectrum of α Scorpii.

Figures 2 and 3 were photocopied from the prints made of Fr. Secchi's drawings as published in *Sugli Spettri Prismatici delle Stelle Fisi.*

Fr. Secchi made five distinct classifications of stellar spectra during the ten years he devoted to this work. His first classification appeared

in 1863; improved and corrected versions of this were published in August and in October of 1866, in 1867, and finally in August of 1868. Now, these changes throughout the years consisted chiefly in refinements of criteria for the separate spectral classes and in changes in the numbering of the types. Perhaps we should point out here what we shall have occasion to develop more fully further on, *viz.*, that while Fr. Secchi's classification did not claim to be a genetic theory of the development of stars from class to class, nevertheless it did recognize the different physical conditions which obtained in the different classes.

On July 15, 1863, in a report to the Academie des Sciences, Fr. Secchi announced the results of his earliest observations, in which he first classifies stars according to their spectra. He prefaces his report with a note on the meaning of the spectrum analysis of the stars:

> The study of the spectra of heavenly bodies has a two-fold significance: first, to establish the existence and nature of their atmospheres, and second, to be able to answer certain questions about the very interesting order in the universe, questions above all pertaining to the motions of the stars.[14]

Fr. Secchi's first class included the colored stars, that is the red and yellow stars. These spectra are characterized by the presence of dark bands, whose position agreed in general with the strong rays of the solar spectrum, which Fraunhofer had observed. In this class Fr. Secchi placed Antares, Betelgeuse, Aldebaran, and Arcturus. The second class was the class of the white stars like Sirius, Rigel, Castor, Vega, etc. These stars showed more discontinuities than those of the first class. Further, the lines appeared to be sharper and more defined. For this, his first classification, Fr. Secchi made observations on 35 of the brightest stars.

In a report to the French Academy written on February 10, 1866, Fr. Secchi submitted[15] a detailed study and diagram of the spectral lines of two stars, Betelgeuse, the model of the colored stars of Class One, and Sirius, the model of the white stars of Class Two.

August of 1866 saw the first modification of Fr. Secchi's original scheme. This is announced in a note to the Academy:

> After these latest studies, I believe that it is better to divide the stars into three classes: first, the colored stars of the type of α Orionis, which have spectra with wide bands; second the white or feebly colored stars such as Arcturus whose spectra are crossed by fine lines; third, the blue stars of which Sirius and Vega are types. These are the most numerous and are featured by three large bands in the blue and violet regions of the spectrum.[16]

In the following month, Fr. Secchi[17] made a further division of the white stars to care for the "Orion" stars. He regarded the stars of this constellation (α Orionis being excepted) as modifications of the first

[14] *C. R.* (*Comptes Rendus*), **57**, p. 71.
[15] *C. R.*, **62**, p. 591.
[16] *C. R.*, **63**, p. 366.
[17] *C. R.*, **63**, p. 623.

type. He pointed out that these stars had a common type with fine lines and a rather prominent line in the place of the solar "F" line. He further observed that there were no larger bands visible except for some faint bands in the violet.

In October of 1866, Fr. Secchi announced[18] the publication of the first catalogue of stellar spectra. Now this catalogue included only 220 stars, something less than one-thousandth of the number to be catalogued some sixty years later in Miss Cannon's Henry Draper Catalogue. That Fr. Secchi himself was well aware that he was only scratching the surface is clear from an observation made about this time:

> It would be absurd to wish to exhaust in a first research the whole new field of stellar spectroscopy.[19]

In April of the following year, Fr. Secchi published[20] a Catalogue which extended the number of stars of known spectral type from 220 to 316. There is no significant change in the numbering or ordering of the types but the existence of intermediate types began to loom large as a future necessity. For such questions as these were arising: Where were the Orion stars to be placed? How should emission-line stars like β Lyrae and γ Cassiopeiae be classified? What should be done about red stars like Aldebaran, whose spectra approached in appearance the spectra of the solar type?

Later on in 1867, Fr. Secchi in the *Memorie della Societe Italiana delle Scienze* announced a new ordering of his spectral types. This order he kept throughout the rest of his work and is the one specified by all who speak of the "Secchi types." He described the new arrangement as follows:

> The stars may be considered as belonging to three main types: the first type, which include the white stars, stars like α Lyrae; the second type, the yellow stars like α Bootis; the third type, the red and orange colored stars like α Herculis and α Orionis.[21]

Now in this arrangement of the different types, Fr. Secchi was foreshadowing the order of the spectral sequence as is commonly known today. But more of this later.

The fact that Fr. Secchi actually employed the lines of the spectrum rather than the mere colors of the stars as the chief criteria of his classification is shown in a note of December, 1867, where he announces to the Academy:

> The three principal lines of hydrogen coincide with the black rays of the white stars of the first type. . . The line corresponding to H_α is present also in stars of this type.[22]

Just about this time, Fr. Secchi became aware of the fact that some

[18] *C. R.*, **63**, p. 621.
[19] *C. R.*, **63**, p. 265.
[20] *Memorie della Societe Italiana delle Scienze*, Vol. I, p. 67, 1867.
[21] *Ibid.*, p. 105.
[22] *C. R.*, **65**, p. 979.

stars exhibited spectra which seemed to stand as intermediate types. For in his communication of January 20, 1868, he wrote:

> The red stars are generally stars of the third type, however, when their color is pale they may be considered as midway between the second and third types.[23]

This process of continuous scrutinization of the stars he was classifying led Fr. Secchi to consider the possibility of the existence of a fourth type of spectrum. This may be seen from another portion of his January note:

> Stars which do not belong to the three established types are rare. I have met one extraordinary star, which appears in Lalande's catalogue as R.A. $4^h\,49^m\,10^s$ and Dec. $+0°\,59'$. I believe that this curious spectrum is only an exaggeration of the third type. However, I cannot be sure until I check further, after this preliminary general survey is completed.[24]

This suspicion of a fourth type of stellar spectrum was confirmed by Fr. Secchi. The confirmation was published in his article of August, 1868:

> There is a complete opposition between the third type and this fourth type. The two spectra are not merely modifications of the same type they are due to completely different substances. The feebleness of the light of these stars, which prevents us from using a slit spectroscope, hinders us from making the strict identification we would like to make. We can say, however, that there is a marked analogy with the reversed spectrum of carbon.[25]

Today we know that the Swan bands of carbon are the recognized criteria for the stars of Classes R and N, which are the modern counterparts of Fr. Secchi's fourth type. This type spectrum consists of three principal luminous bands in the blue, green, and red and these bands are separated by dark intervals. What distinguishes the stars of the third type from those of the fourth is not merely the width of the zones, but more especially the fact that, in the spectra of the fourth type, the light in the zones falls off abruptly on the edge of shorter wavelength, while it fades off gradually to darkness on the edge of longer wavelength. In spectra of the third type, the distribution of light is reversed.

In July of 1869, Fr. Secchi encountered a serious difficulty in classifying the spectra of the small bright-line stars discovered by Wolf. It must be added further that Fr. Secchi never successfully extricated himself from this difficulty. In writing to the French Academy, he says:

> These three (Wolf) stars all belong to the same type and all three have a principal blue ray, very beautiful and very strong, and also a group of rays in the orange. It would appear that these stars form one of the numerous varieties of the fourth type of stars, which contain carbon.[26]

He makes this same observation in his next letter[27] to the Academy on

[23] *C. R.*, **66**, p. 124.
[24] *C. R.*, **66**, p. 125, *et seq.*
[25] *C. R.*, **67**, p. 373.
[26] *C. R.*, **69**, p. 39.
[27] *C. R.*, **69**, p. 163.

July 19, 1869. More than a score of years elapsed before this error of classification was rectified by Professor E. C. Pickering[28] of Harvard. For in 1891, Professor Pickering proposed a "Fifth Type of Spectra," which included the "Wolf stars and the planetary nebulae." Indeed, this type has become so closely associated with Fr. Secchi's types that it is sometimes forgotten that it is to Professor Pickering and not to Fr. Secchi that the credit for this type belongs.

In 1870 was published[29] the first edition of Fr. Secchi's work, "Le Soleil." The book is largely a résumé of the astrophysical data compiled by Fr. Secchi and others concerning the physical and chemical conditions prevailing on the sun. In the final portion of the work, he summarizes his scheme of spectral classification, and gives a description of the methods he followed and the results he achieved. There is no change in the ordering of the types; more attention is given, however, to the intermediate types and to certain extraordinary groups of stars. One of the latter is the group of Orion stars, which in Fr. Secchi's classification are listed as Type I O, and which are known generally today as the helium B-stars. Another peculiar group formed what Fr. Secchi called the "fifth class of stars." This type spectrum showed some resemblance to the Orion stars but showed a direct line spectrum of hydrogen. The prototype of this fifth class was γ Cassiopeiae, which Fr. Secchi observed to possess two bright lines in place of the "F" and "C" rays. In the second edition[30] of "Le Soleil" there are no additions or outstanding changes in the scheme of classification.

In Table I is presented a summary of the different spectral classifications. It covers the work of the early classifiers, including that of Fr. Secchi; for comparison with modern classifications, Miss Cannon's scheme is added.

Having sketched the development of Fr. Secchi's system of classifying stellar spectra, we shall speak now of some of the interesting features, the astrophysical "by-products" of this work. We use the term advisedly; for Fr. Secchi, as we pointed out before, had no prefabricated theory of stellar evolution to test in his work. Indeed, he mentions this explicitly in "Le Soleil":

> Up to the present we have done nothing but classify the stars into several types according to the differences displayed by the luminous radiation which they send us.[31]

We must not conclude, however, that Fr. Secchi blinded himself to everything but the criteria for spectral types. He was too true a scientist for that. We shall consider some of these interesting incidental

[28] *A. N.*, **127**, p. 1, 1891.

[29] "Le Soleil" in its first edition was published by Gauthier-Villars in Paris in 1870.

[30] "Le Soleil" in its second edition was published by Gauthier-Villars of Paris in two volumes: Vol. I in 1875, Vol. II in 1877. In 1878, Fr. Secchi died.

[31] "Le Soleil," Vol. II, p. 459.

TABLE I

SUMMARY OF SPECTRAL CLASSIFICATIONS

FRAUNHOFER	DONATI	RUTHERFURD	CARPENTER	SECCHI				CANNON
				1863	1866	1868	Adopted	
							$V_{Pickering}$	P-O
							I 0	B0-B7
		Group Three (Spica, Rigel)						
							I 0-I	B8-B9
Stars with Blue Bands	White Stars	Group Two (Sirius)	Group Two (White Stars)	Class Two (White Stars)				
							V_{Secchi}	Oe5p-B9p
					Type One (Vega)	Type One (Vega)	I	A0-F2
							I-II	F5
Solar-type Stars	Yellow Stars		Group Three (Solar Stars)		Type Three (Sun)	Type Two (α Bootis)	II	F8-K2
							II-III	K5
	Orange Stars	Group One (Stars with Lines and Bands)	Group One (Red Stars)	Class One (Stars with Bands)				
Red Stars	Red Stars				Type Two (α Ori)	Type Three (α Her)	III	M
						Type Four (152 Schjellerup)	IV	R-N

topics treated by Fr. Secchi during these years of research, among which we can select the following:

1. The development of stars in a temperature sequence.
2. The space distribution of stars of different spectral classes.
3. The radial velocities of stars.
4. The peculiarities of the spectra of variable stars.

In his note of April, 1867, to the French Academy, Fr. Secchi had pointed out that in the red stars the ray at "D" is "enormously" broadened, very much more than the ordinarily sharp line due to sodium. His concluding remark discloses the first hint given by Fr. Secchi at anything like a temperature sequence:

> This broadening indicates that these red stars are enveloped in atmospheres of great absorbing power, whose nature will not be known until the chemists have separated in spectra just what belongs to the nature of the substance and what to its temperature.[32]

July of 1869 saw Fr. Secchi pointing[33] out that new conditions of temperature and pressure may explain the differences among the spectral types. Just about this time, Fr. Secchi began some experimental work in the physics laboratory in order to observe the effects of varying conditions of temperature and pressure on laboratory spectra. In the course of his experiments, he noticed[34] that the spectrum originating in the bulbs of Geissler tubes was different from that coming from the body of the tube; this observation led him to the conclusion that under the same pressure, temperature differences, which obtain in different parts of the circuit, are sufficient to cause changes in the spectrum.

In July of the following year, 1870, Fr. Secchi wrote to the Academy:

> It is without doubt too early for us to point to definite conclusions, since our data are still too incomplete, but I believe we are not going too far from the truth of the observed facts, when we say that not only have the atmospheres of the stars of the third type, and above all of the fourth type compositions quite different from that of our sun, but that they appear to be at a temperature sufficiently low as to give spectra characteristic of gases at a low temperature.[35]

We can see from this that Fr. Secchi, although he did not make his classification of spectral types according to any scheme of stellar evolution, still would not have been too surprised to find that his arrangement of stellar spectra had foreshadowed in large part what is known today as the "main sequence and its branches."

The second astrophysical "by-product" of Fr. Secchi's years of research consists in the several references to the space distribution of stars of similar spectral classes. His first contribution to this very important astronomical topic occurs as a casual remark in February, 1866.

[32] *C. R.*, **64**, p. 778.
[33] *C. R.*, **69**, p. 163.
[34] *C. R.*, **69**, p. 1076 *et seq.*
[35] *C. R.*, **71**, p. 254.

After discussing the many peculiarities of the spectra of the Orion stars, he observes:

> It is remarkable that in the large space covered by this constellation, one rarely finds types different from this type. I ought to add that it is common to find in the same region of the sky stars of the same types which are bunched together. Now this result certainly ought not to be attributed to chance.[36]

In 1869, when attempting to classify the Wolf stars, Fr. Secchi points out[37] as an important fact that these stars of the same type are all neighbors, a fact which seemed to him to bespeak a common origin. Again in "Le Soleil" he mentions[38] a similar grouping of yellow stars in the regions of Cetus and Eridanus.

The radial velocity of the stars is the third topic incidental to Fr. Secchi's classification which we may profitably consider. In his very first communication to the French Academy in July of 1863, Fr. Secchi, after speaking of certain problems encountered in the study of planetary spectra, adds:

> The study of the spectra of the stars is of even greater importance, for a displacement of their rays would furnish a proof of their movement; however, the precision with which we can make these observations is still far from the accuracy demanded by the problem.[39]

No further mention is made of the role which stellar spectra can play in determining the motion of the stars until he explains in a note of September, 1866, to the Academy how such motions might be detected:

> By comparing the position of a ray of the same star with observations of great accuracy, we may be able to decide whether the bands, which are due to the same substance, always hold the same position, or, if the contrary is the case, whether we may be able to arrive at a knowledge of the motions of the stars themselves according to the theory of Doppler.[40]

Fr. Secchi did his best to check on the Doppler effect, which had been announced in 1841; however, he met with no success. In this line of research, perhaps above all others, a photographic record would have stood him in good stead. Later on, in 1868, he shows us that this problem was still high on his list of "solvenda"; for he comments[41] on the imperfections of measurement which prevented him from arriving at any conclusion worthy of trust; he mentions, too, the help and encouragement received from M. Fizeau. Yet, he had to conclude that for stars of the type of Sirius, which he considered best suited for the detection of any line shifts, there was no appreciable displacement of the spectrum lines. Three years after this, in 1871, the first confirmation of the Doppler-Fizeau effect was obtained by H. C. Vogel[42] when he

[36] *C. R.*, **63**, p. 623.
[37] *C. R.*, **69**, p. 163.
[38] "Le Soleil," Vol. II, p. 459.
[39] *C. R.*, **57**, p. 74.
[40] *C. R.*, **63**, p. 623.
[41] *C. R.*, **66**, p. 398.
[42] *A. N.*, **78**, p. 250.

tested the theory on the limbs of the sun and thus detected its motion. Still later, Sir William Huggins and Professor Vogel each succeeded in determining the speed of motion of different stars.

Another significant astrophysical "by-product" of Fr. Secchi's classification was his study of the peculiarities of the spectra of variable stars. In his study of the spectrum of α Orionis made in February, 1866, he mentions[43] the possibility of finding a variability in the colored bands similar to the well-known variations of light intensity. His most significant observation on this subject occurs in his article in the *Chemical News* for October, 1868:

> A very remarkable conclusion arrived at is that all spectra of the third and fourth type belong to the variable stars. The representative of these is Mira Ceti. This star has been examined carefully and, even when it is only of the seventh magnitude, it has the same spectrum of its type, but it is reduced to its few bright lines. Further, α Orionis appears to be in the same condition. α Tauri and Antares this year appeared to be smaller and of a more ruddy hue than in the past year, and in α Tauri, there appeared columns that were not visible the year before. So that it is evident that the changes in these stars depend on a periodical change which occurs in their atmospheres. It is not so however, with Algol, which has the very same spectrum of the first class or type during each phase of its variation. This induces me to believe that there the variation is produced by the passage of an opaque body interposing itself between us and the star, thus giving an example of an eclipse of a fixed star by its own obscure planet.[44]

In this paragraph we have the implicit discovery of two very important facts:

> 1. That there exists a relation between the period and the spectrum of a star.
>
> 2. That there is a distinction between eclipsing and pulsating variables.

With Fr. Secchi's death in 1878, the early years of stellar spectroscopy came to a close. The chief advance in subsequent years was the successful application of the principles of photography to problems involving stellar spectra. Now, permanent records could be made, and measurements once made could be rechecked; now, fainter lines could be recorded; and now, the observable spectrum could be extended photographically into both the ultra-violet and the infra-red. What seems remarkable in all this is that Fr. Secchi's work should be considered of any value at all. To be sure, it has been superseded by more elaborate and more detailed schemes of spectral classifications, the most notable of which are the I.A.U. approved Henry Draper Catalogue and the most recent of all classifications the two-dimensional Morgan-Keenan-Kellman system. Still the fact that the I.A.U. allows[45] the employment of Fr. Secchi's types "in cases of great uncertainty" shows how he is still offering his giant's shoulders to present day astrophysicists.

Were he with us today, he would doubtless be very much amazed at

[43] *C. R.*, **62**, p. 591.
[44] *Chem. News*, Vol. XVIII, p. 19, 1868.
[45] *Transactions of the International Astronomical Union*, Vol. 1, p. 96, 1922.

the many improvements in the techniques of stellar spectroscopy, at the refinements of spectral sub-divisions, line intensity ratios, and most of all at the wealth of information amassed concerning the chemical and physical conditions of the different stars and derived from the studies of the profiles of spectrum lines. Indeed, Fr. Secchi would see that stellar spectroscopy had gone far, far beyond the achievements of his day, even as he predicted it would. Still he would observe that despite certain changes, the scheme of stellar spectra still preserved the general outline of his classification. Most especially, I believe, he would note with satisfaction how the branching of the stellar sequence at Class K had been well marked out by the division of stars into types three and four of his own classification.

We shall sum up this study of Fr. Secchi's classification of stellar spectra with two sentences placed by him near the end of the last of his works. These sentences give both a picture of the man and a delineation of the motive which inspired his work:

> 1. There remain many things for us to learn; for nature is inexhaustible in its wonders; when we think we have arrived at the end, we find that it is only the beginning.[46]
>
> 2. God alone can perfectly comprehend his work in the universe. Fortunate is that man who can have a concept grand enough for him to admire the grandeur and beauty of God's work.[47]

It is a pleasure to acknowledge my gratitude to Dr. C. C. Kiess of the National Bureau of Standards and the Georgeown University Graduate School and to Father Francis J. Heyden S.J., Director of the Georgetown College Observatory for their encouragement and assistance in preparing this paper.

[46] "Le Soleil," Vol. II, p. 483.
[47] *Ibid.*, p. 465.

Structure and Composition of Canyon Diablo Meteorites as Related to Zonal Distribution of Fragments

By H. H. NININGER

We have previously pointed out that there is a concentric zonal distribution as well as a radial distribution of meteorite fragments around Barringer Crater. And that the zonal distribution is very definitely related to specimen size. The metallic specimens found on the crater rim have all, with one exception, been comparatively small, few of them heavier than five pounds and the average less than one-half pound in weight.

The large masses have been found on the plain surrounding the crater rim, usually grouped more or less in clusters, and the clusters

showing a tendency toward radial distribution. Often small masses were also associated in these clusters of large masses on the plain; but the large ones have not been found in association with the abundant small fragments on the rim.

Attention has also been called to the fact that the crater structure exhibits both bilateral and radial symmetry, indicating that the colliding meteorite burrowed into the earth before exploding so that we have a more or less circular explosion crater yet bearing traces of an intrusion furrow.

We have considered that the outlying masses that have been found could not have fallen from space to where they were discovered else they would have been much more deeply buried. The suggestion was made that erosion subsequent to the fall had exposed the deeply buried masses, but studies of soil levels relative to the roots of trees whose ages were approximately determined indicated a very slow rate of erosion for the region, much too slow to account for these surface finds on this basis. The present paper presents two additional observations: (1) We believe that we have discovered how two well-known constituents (schreibersite and cohenite) have performed an important role in the demolition of the great nickel-steel meteorite, and at the same time protected certain of its remnants from any rise in temperature sufficient to alter their structure. (2) We have discovered a definite relationship between certain internal structures found in the Canyon Diablo meteorites and their location relative to the crater.

As long ago as 1894, Huntington of Harvard called attention to the very irregular distribution of Widmanstätten figures in the Canyon Diablo irons. Any good photograph of a large etched section reveals that the inclusions of cohenite, schreibersite, troilite, and carbon are also very unequally spaced. Some specimens are so richly impregnated with the very brittle phosphide and carbide that an irregular mass measuring ¾ square inch in cross section and appearing perfectly solid was readily split by means of a cold chisel under three blows from a three-pound hammer. On the other hand, specimens of the same size, free from these minerals, could not be so divided by thirty minutes of vigorous effort.

Years ago, our attention was called to the fact that very few of the small irons from around the crater showed good clear figures on etching, while nearly all of the large masses sectioned etched into a strikingly beautiful pattern. This fact had been noted by Mr. Colvocoresses also, who, like myself, had attributed it wholly to the matter of size, on the assumption that the heat of atmospheric friction and of impact had heated the small fragments throughout, while the larger masses, heated only superficially, had lost their alteration zone through weathering.

It was not until recently that the relation was discovered between the capacity for producing good Widmanstätten figures and the locations where various specimens had been found. We now know where

to find small specimens which will develop as clear Widmanstätten figures as can be seen in the best of the large irons.

In the year 1948 when a hundred small irons from the crater rim were sectioned and etched, we were surprised to discover that not even one of them produced really good figures. All showed evidence of having been subjected to 800 to 900 degrees centigrade. In years past, equally large numbers of small irons had been sectioned and there were almost always a few which showed good etching patterns. This was confusing. Another fact had for many years been a puzzle also. That was: if the meteorite really exploded due to the tremendous heat of impact, how did the large surviving fragments escape being heated sufficiently to dim the Widmanstätten pattern?

After the recent experiments which demonstrated the very great weakening effect of cohenite and schreibersite, we thought we began to understand how the meteorite could have shattered as it contacted the lithosphere and by this means, *previous to the true explosion*, set free without any great amount of heating fragments whose clear-cut etching patterns had been puzzling us.

If such a pre-explosion fragmentation had been responsible for the preservation of Widmanstätten structure in the large fragments found remote from the crater, then perhaps it would also have allowed some of the small associated fragments found in these outlying areas to escape without heat alteration.

The small specimens that we had etched years ago had been purchased from collectors who had gathered them at random, and we could not be sure where they had been found. We knew that those studied in 1948 had been taken from the upper half of the rim slope. We decided to test some small specimens from outlying points.

Already, as a result of the survey supported by American Philosophical Society Grant No. 1039 (1947) and by contributions from Messrs. Alfred Knight and Fred Luthy, we had two small irons from state section 26, southwest of the crater about one and one-half miles. We now sent a collector to other sections of state land farther west and south in areas whence had come some of the large irons.

Eight specimens of two pounds or less were tested from points one to three and one-half miles distant from the crater rim. Without exception, these showed as clear Widmanstätten patterns as had any of the large irons we had seen. Even a small iron of only fifty-three grams was polished and etched and showed no evidence of heat.

We believe that these investigations strongly indicate that the outlying meteorite deposits have had a different origin from those which lie on or near the crater rim, and further tests on specimens from other outlying points are planned.

This then, raises other questions: (1) Were these outliers stripped from a large mass during its flight through the atmosphere? (2) Do

they represent the peripheral members of a swarm? (3) Were they torn from a large mass as it entered the soil?

To the first of these, the answer seems to be negative for the reason that all investigators now agree that the angle of incidence was forty-five degrees or more from the vertical, and all records of known falls indicate that in this instance any stripped-off fragments should lie in an ellipse whose greatest elongation should be toward the north-northwest—the direction from which the crater-forming mass seems to have come. On the contrary, the records indicate an almost circular distribution with a somewhat shortened radius in this direction.

Regarding the second question, if the crater had been formed by a closely packed swarm, we should expect the larger members of the swarm to be at its center and the smaller ones at the periphery, the very opposite of the known distribution.

Third. We believe that due to the fact of a very unequal distribution of two extremely brittle minerals, the large crater-forming mass underwent a degree of fragmentation as it encountered the lithosphere. As the compressed block of air which it carried on its forward surface encountered the earth, forcing a violent deceleration, the mass sheared along planes of weakness where the brittle constituents were concentrated. The heat of shearing occasioned vaporization of schreibersite and troilite, producing localized explosions which projected swarms of various-sized fragments in different directions. The material thus separated from the main mass along lines of weakness was spared internal heating, and any alteration effects of external heating in the form of a peripheral zone of granulation has long since been removed by exfoliation of oxides.

This process preceded by seconds the final explosion which took place in the depths of the crater as the surviving portion was brought to a

1 2 3

1—Etched section of small iron found three miles from Barringer Crater showing Widmanstätten figures, with cohenite and schreibersite.

2—Etched section of iron from rim of crater, rich in cohenite, with some schreibersite in lower left.

3—Same as No. 2 but with a schreibersite inclusion in upper center.

Neither No. 2 or No. 3 shows Widmanstätten figures.

final stop by resisting rock strata. The fragments which survived *this* explosion were more highly heated, sufficient to destroy the Widmanstätten pattern.

American Meteorite Museum, Winslow, Arizona.

Eclipse Lists in the Alphonsine Tables

By WILLIAM D. MORGAN

In the later printed editions of the Alphonsine Tables, solar and lunar eclipse lists have been published which represent most of the eclipses visible in Europe over a fifty-year period from 1525 to 1575. These eclipse lists appear in the edition published at Venice in 1524, and in those which were published at Paris in 1545 and 1553. They do not appear in the Venice editions of 1483, 1492, and 1518. The remaining printed editions, Venice 1488, 1490, and 1521 and Madrid 1649 are not presently available for study.[1]

In the case of eclipses of the sun, these lists do not attempt to detail the shadow path. The principal tabulated quantities are the times of mid-eclipse, the total duration of the eclipse, and in the case of total lunar eclipses, the duration of the total phase. The times are given for Rome, and it may be of some interest to compare these data with the corresponding data published in more modern tables.

The French chronological work 1, Art de Verifier les Dates, the first edition of which was published in 1750, contains a list of both solar and lunar eclipses visible in Europe from the beginning of the Christian era to the year 1800. In this list no distinction is attempted between total and annular eclipses of the sun, but a distinction is indicated between partial and total eclipses of the moon. The times of mid-eclipse are given to the nearest integral hour for Paris local time, no further data being supplied. On account of the somewhat extensive period of time represented by these tables, they are often regarded as somewhat transitional between the late medieval lists and the great modern work of Oppolzer. The times of mid-eclipse as shown in 1, Art de Verifier les Dates, are sometimes in error by more than an hour, and seem to be rather less trustworthy than the times as shown in the Alphonsine Tables.

The lunar eclipse lists published in Oppolzers' "Canon der Finsternisse" do not always give the duration accurately, as the author himself states on page xxxiii of the work, the half duration which he tabulates may sometimes deviate from the true value by several minutes, and it has been found by comparing his data with the *American Ephemeris* that there is this degree of deviation in some cases.

More recently Oppolzer's elements have been corrected by Schroeter, and corrected elements have been published for all central eclipses of

	Date of Eclipse	Alphonsine Tables			L'Art de Verifier Les Dates	Oppolzers' Canon Der Finsternisse			J. F. Schroeter 1923		
		Time of Mid-Eclipse	Duration	Duration of Totality	Time of Mid-Eclipse	Time of Mid-Eclipse	Duration	Duration of Totality	Time of Mid-Eclipse	Duration	Duration of Totality
		h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
M	1525 Dec. 29	21 37	3 28	0 46	19 50	21 20	3 24	0 48	21 22	3 24	0 48
M	1526 Dec. 18	22 01	3 36	1 02	20 50	21 24	3 32	1 16	21 26	3 32	1 16
M	1529 Oct. 17	7 54	3 14		6 50	7 08	3 20	0 24	7 11	3 20	0 24
S	1530 Mar. 29	5 53	1 54		8 50	6 02.6					
M	1530 Oct. 6	23 42	3 40	1 25	22 50	22 46	3 40	1 32	22 49	3 40	1 32
M	1533 Aug. 4	23 26	3 32	0 46	24 50	23 14	3 26	0 52	23 16	3 26	0 52
S	1534 Jan. 14	13 08	1 54		11 50	11 44.7					
M	1534 Jan. 30	2 01	3 28	0 56	1 50	1 33	3 32	1 12	1 36	3 32	1 12
S	1536 June 18	13 38	2 06		12 50	12 46.8			12 48.5		
M	1536 Nov. 27	17 57	3 14		17 50	17 10	3 08				
M	1537 May 24	19 37	3 48	1 40	19 50	19 29	3 44	1 42	19 32	3 44	1 42
M	1537 Nov. 17	2 39	3 38	1 30	0 50	1 50	3 40	1 36	1 53	3 40	1 36
M	1538 Nov. 6	17 07	2 06		16 50	16 15	2 06				
S	1539 Apr. 18	15 54	1 54		15 50	14 14.5			14 17.4		
S	1540 Apr. 7	4 51	2 04		4 50	5 11.8			5 14.4		
M	1541 Mar. 12	4 10	3 38	1 21	2 50	4 07	3 38	1 26	4 10	3 38	1 26
M	1544 Jan. 10	5 49	3 28	0 41	4 50	5 35	3 24	0 44	5 37	3 24	0 44
S	1544 Jan. 24	8 52	2 06		7 50	9 03.9			9 06.6		
M	1544 July 4	20 07	3 42	1 30	19 50	20 02	3 40	1 36	20 05	3 40	1 36
M	1544 Dec. 29	6 03	3 36	1 03	4 50	5 28	3 34	1 18	5 30	3 34	1 18
S	1545 June 9	8 24	1 36		8 50	8 44.2					
M	1547 May 4	22 03	3 00		20 50	21 59	3 00				

(Continued)

	Date of Eclipse	Alphonsine Tables			L'Art de Verifier Les Dates	Oppolzers' Canon Der Finsternisse			J. F. Schroeter 1923		
		Time of Mid-Eclipse	Duration	Duration of Totality	Time of Mid-Eclipse	Time of Mid-Eclipse	Duration	Duration of Totality	Time of Mid-Eclipse	Duration	Duration of Totality
		h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
M	1547 Oct. 28	16 31	3 20		15 50	15 40	3 18		15 43	3 18	
S	1547 Nov. 12	13 44	2 16		12 50	13 02.6					
M	1548 Apr. 22	23 00	3 46	1 33	22 50	22 22	3 40	1 36	22 24	3 40	1 36
M	1551 Feb. 20	19 57	3 32	1 03	18 50	19 39	3 30	1 06	19 42	3 30	1 06
S	1551 Aug. 31	13 36	1 52		13 50	12 58.8	3 06				
M	1554 Dec. 9	2 14	3 34		1 50	1 30	3 06				
M	1555 June 5	2 32	2 06	1 40	1 50	2 33	3 44	1 44	2 35	3 44	1 44
S	1556 Nov. 2	6 14	2 16		7 50	7 12.3			7 13.8		
M	1556 Nov. 17	1 53	2 28		0 50	1 03	2 10				
M	1558 Apr. 2	0 07	3 36		23 50	23 42	3 10				
M	1559 Sept. 16	17 05	3 44	1 24	16 50	16 59	3 38	1 26	17 01	3 38	1 26
S	1560 Aug. 21	12 54	1 48		13 50	12 23.5			12 26.2		
M	1562 July 16	3 40	3 38	1 21	2 50	3 35	3 38	1 28	3 38	3 38	1 28
S	1563 June 20	16 56	2 00		16 50	15 17.7			15 19.4		
M	1563 July 5	21 01	3 22		20 50	20 42	3 20	0 32	20 45	3 20	0 32
M	1565 Nov. 8	1 14	3 16		0 50	0 21	3 14				
M	1566 Oct. 28	16 33	3 40	1 30		15 29	3 40	1 36	15 31	3 40	1 36
S	1567 Apr. 9	11 42	2 04		10 50	10 56.6			10 58.7		
M	1569 Mar. 3	4 22	3 30	0 55	4 50	4 05	3 28	0 58	4 08	3 28	0 58
M	1570 Feb. 20	18 41	3 34	1 09	18 50	18 13	3 34	1 18	18 15	3 34	1 18
M	1570 Aug. 15	20 59	3 40	1 24	19 50	20 45	3 38	1 28	20 48	3 38	1 28
M	1573 Dec. 8	19 49	3 40	1 34	18 50	19 13	3 40	1 36	19 16	3 40	1 36

M = Lunar Eclipse.
S = Solar Eclipse.

the sun and moon visible in Europe between the dates 600 and 1800, A.D. The work of Schroeter tabulates directly the times of beginning and ending of the partial and total phases, and the middle times of each lunar eclipse.[2]

In the accompaning comparison, the time of mid-eclipse, has, in the case of the Alphonsine lists, been reduced from Rome to Greenwich, and in the data excerpted from 1, Art de Verifier les Dates, the times have been reduced from Paris to Greenwich. Thus the middle time will in each case be expressed in Greenwich Civil Time.

During the half century here under consideration, the times of mid-eclipse, as published by Schroeter, occur consistently several minutes later than the corresponding times given by Oppolzer, but the durations of the total phases for all lunar eclipses tabulated remain the same.

It will be seen that while the times of mid-eclipse as tabulated in the Alphonsine Tables are sometimes in remarkably close agreement with modern determinations, there is also frequently a very wide disagreement, for which there is no very obvious explanation. The work contains frequent misprints and errors, which may possibly explain certain of these differences, but it is of course unsafe to assume such an explanation where positive evidence is wanting. An instance of a printer's error, or an error on the part of the calculator, which is quite obvious, is in connection with the total lunar eclipse of June 5, 1555, where the entire duration is given in the Alphonsine lists as 2 hours 6 minutes and the duration of the total phase as 1 hour 40 minutes. Such an eclipse would be impossible, as it would mean that the eclipse becomes total only thirteen minutes after it begins. The whole duration in this case differs by 1 hour 38 minutes from that given by Oppolzer and Schroeter.

For the duration of entire eclipse and for the duration of the total phase, the difference between the values given in the Alphonsine lists, on the one hand, and those of Oppolzer and Schroeter on the other is usually of the order of several minutes. In some cases much greater differences exist, and in others the agreement is indeed very close. On the whole we must perhaps concede that with the materials available, the astronomers of four centuries ago are entitled to no inconsiderable amount of credit for the degree of accuracy with which these eclipse lists were executed. The tables themselves were based on the *Almagest* with its complicated and erroneous system of epicycles, deferents and eccentrics. Gravitational theory was as yet completely undeveloped, but without modern aids, the astronomers of that period were somehow able to reach results of considerable accuracy.

REFERENCES

[1] Houzeau & Lancaster list ten printed editions of the Alphonsine Tables as follows: Venice 1483, 1488, 1490, 1492, 1518, 1521, 1524, Paris 1545 and 1553, also

Madrid 1649. The Venice editions of 1483, 1492, 1518, 1524, and the two Paris editions are in the author's library.

[2] J. Fr. Schroeter. Spezielier Kanon der Zentralen Sonnen-und Mondfinsternisse, Welche innerhalb des zeitraums von 600 bis 1800 N. Chr. in Europa sichtbar waren. Kristiana 1923.

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Radio Whistles

By SIDNEY VAN DEN BERGH

During recent months a preliminary investigation has been made of radio whistles using a Philips PX281u1 radio receiver with nondirectional antenna. The object of the observations was to obtain data that might be of use in the investigation of a possible relation between meteors and radio whistles.[1] Observations were made on short (15-50m) and medium (185-575m) wavelengths. All the data presented in this paper are from the short-wave observations only. This material consists of 66 individual whistle observations.

The following data were recorded of each whistle:

1. Time of observation (E.S.T.)
2. Loudness of each whistle on a scale from 0 to 6, where 6 is the faintest audible whistle (m)
3. Duration in seconds (d)
4. Time interval between whistles heard within five seconds of each other (Δ)
5. Variation of pitch (p).

Example of Observing Sheet

Station: P.C.J., The Netherlands—31.28 meters. Date January, 1949

E.S.T.	No. of Mts.	m	d	Δ	p
1300-05	0				
05-10	2	3 5	0.3 0.4	½	H-L H-L
10-15	1	6	0.2		H-L

Intensity of sound. If we assume that a Fechner logarithmic relation holds for the observed whistle intensities we may compare the intensity distribution of the whistles with the magnitude distribution of meteors (Fig. 1).

Durations. A comparison between the observed duration of the whistles and the duration of visual meteors shows that the duration of radio meteors is in general considerably shorter than that of visually observed meteors (Fig. 2). This might be explained by assuming that we received reflections only from the most densely ionized part of the trail or from specially oriented parts.

Observations on medium wavelengths (185-575m) seem to indicate a slightly longer duration.

[1] *Pop. Astr.*, **56**, 506, 1948.

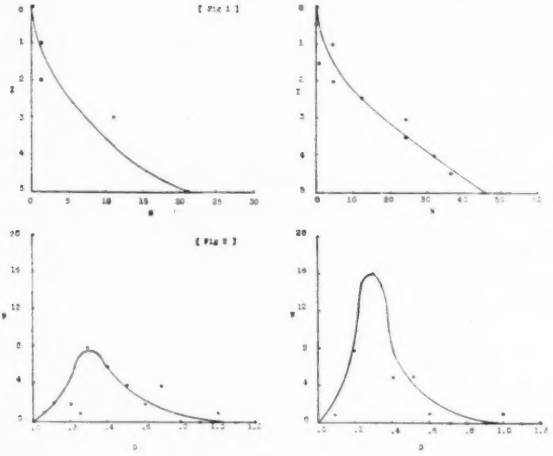

FIGURE 1
Left—Radio Observations
Right—Visual Observations

FIGURE 2
Left—Visual Observations
Right—Radio Observations

Time intervals. Our observations show that the whistles do not have a random distribution. Of 66 whistles observed 40% occurred within 5 seconds of each other, as shown in the table.

40	were single	(1).....60%
10	were double	(2).....15%
3	were triple	(3)..... 5%
8	were quadruple	(4).....12%
5	were quintuple	(5)..... 8%

As the mean number of whistles was about 2 per hour, we can calculate the number of whistles that we would expect per 5 seconds interval assuming random distribution.[2]

Let C be the number of 5 seconds intervals with 2 whistles and let n_o be the mean number of whistles per 5 seconds. For $n = 2$ we would expect from Poisson's equation:

$$C = \frac{m n_o^n e^{-n_o}}{n!}$$

where m is the total number of five seconds intervals. From our observations we have:

$$n_o = 39/11390 \qquad m = 11390 \qquad \text{and } n = 2.$$

These values do not include the meteor shower of January 20, 1949,

[2] D. Hoffleit. *Harvard Circular* 420.

and whistles observed outside regular observing periods. Substitution of our values in Poisson's equation gives $C = .07$, but our observations indicate that $C = 5$, so that the whistles evidently do not have a random time distribution for $n = 3$, 4, and 5 the odds are still more against random distribution.

Pitch. All short-wave whistles change from high to low. It is not yet certain if this also holds for medium wavelengths.

Bursts and showers. On going over the tabulated observations it becomes clear that the radio whistles occur in bursts. A good example of such a burst was observed on January 31, 1949, 1900, E.S.T. Minor bursts were observed on December 16, 1948, and January 23, 1949.

We had the good fortune to be observing on January 20, 1949, at about $13^h\ 57^m$ E.S.T.[3] Suddenly the number of whistles started to increase till between 1400 and 1405, E.S.T., the rate would have corresponded to 144 whistles per hour, as against about 2 normally. The maximum of the shower occurred at 1403, E.S.T. Of the 24 whistles observed during the shower, 42% were members of pairs or groups. (Normally about 40%). No reports of visual observations of a meteor shower have come in, but it is quite possible that the radiant was too near to the sun at the time to permit visual observations. None of the stations that observe meteors by radar was in operation at the time.

The data given above do not enable us to say with certainty that the observed whistles are caused by meteors. For example the percentage of groups was about 10 times as high as the percentage obtained from visual meteor observations,[4] but it is possible that the large area of coverage of the radio receiver is responsible for this. The observational material is at present not extensive enough to determine if there is any daily variation in the number of whistles. As no observations have yet been made during any of the major meteor shower maxima, it has not been possible to identify the nature of the observed whistles with certainty.

In conclusion we should like to thank Dr. A. C. B. Lovell of the Jodrell Bank Experimental Station of the University of Manchester for his kind interest in our work, and Mr. N. C. de Troye for sending us the meteor whistle observations of the Meteor Section of the Netherlands Meteorological and Astronomical Association.

Princeton University Observatory, April 24, 1949.

[3] *B.A.A. Circular*, No. 308, March 15, 1949.
[4] D. Hoffleit, *Harvard Circular* 420.

The Planets in May, 1950

By RAYMOND H. WILSON, JR.

NOTE: The time employed is Central Standard Time unless otherwise indicated. The phenomena have been chosen and described for the North American continent, and especially for the United States. The basic data have been taken principally from the *American Ephemeris and Nautical Almanac*.

Sun. By the end of this month the sun will have climbed northward to nearly 22 degrees north declination. This is within a degree and a half of the summer maximum.

Moon. The phases of the moon will occur as follows:

Full Moon	May 1	11 P.M.
Last Quarter	8	5 P.M.
New Moon	16	7 P.M.
First Quarter	24	3 P.M.
Full Moon	31	7 A.M.

The moon will be at perigee on May 2 and May 30.

Evening and Morning Stars. Saturn and Mars will be near the meridian just after sunset; Jupiter and, later, Venus will appear in the east at dawn.

Mercury. For the first few days of the month Mercury may still be visible, low in the northwest, just after sunset. Then, after passing inferior conjunction on the 14th, it might be picked up in the morning twilight of the last days of the month.

Venus. This planet, now slowly decreasing in brilliance, will be rising almost due east before 3:30 A.M.

Mars. The red planet will be most conveniently situated for early evening observers, since it will be crossing the meridian at 8 P.M. in the middle of the month.

Jupiter. This second brilliant planet will be an hour or two west of the most brilliant Venus. Hence, Jupiter will be rising in the southeast by 2 A.M. in the middle of the month.

Saturn. Saturn will be in Leo, about 10 degrees east of Regulus and 5 degrees west of Mars. Hence, together with the red planet, it will be a very convenient object for evening observations.

Uranus. Uranus will be moving eastward at about a degree northwest of η Geminorum.

Neptune. Neptune will be moving slowly northwestward at about 3 degrees west-northwest of θ Virginis.

Department of Mathematics, Temple University, Philadelphia, Pa.
March 5, 1950.

Occultation Predictions for May, 1950

(Taken from the *American Ephemeris*)

The quantities in the columns a and b are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the

signs into account, by the quantity under a for the star to be observed; similarly, with the latitude, using b; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

Date 1950	Star	Mag.	IMMERSION Greenwich C.T. h m	a m	b m	Angle E from N °	EMERSION Greenwich C.T. h m	a m	b m	Angle E from N °
Occultations Visible in Longitude +72° 30′, Latitude +42° 30′										
May 4	CD—27°11076	6.5	4 36.1	—1.3	+0.6	103	5 48.6	—1.4	0.0	294
28	BD—8°3495	6.4	3 36.5	—1.4	—1.3	115	4 45.7	—1.0	—1.8	312
29	214 G.Virg	6.4	4 13.2	—1.3	—1.4	131	5 22.5	—1.3	—1.4	287
30	47 G.Libr	6.1	4 58.3	—1.7	—0.6	85	6 3.1	—1.3	—1.7	319
Occultations Visible in Longitude +91° 0′, Latitude +40° 0′										
May 4	CD—27°11076	6.5	4 21.2	—0.2	0.0	138	5 19.6	—1.4	+1.0	264
6	183 B.Sgtr	6.2	10 43.9	—2.0	—0.2	87	12 1.6	—1.4	—0.2	244
28	*g* Virg	5.7	2 26.2	—3.3	+1.3	70	3 5.2	+0.5	—3.0	8
28	BD—8°3495	6.4	3 15.5	—1.1	—1.5	147	4 26.0	—1.7	—1.2	290
29	214 G.Virg	6.4	3 55.8	—0.7	—1.6	162	4 54.6	—2.2	—0.5	267
30	47 G.Libr	6.1	4 24.9	—1.8	—0.3	110	5 39.8	—1.6	—1.0	306
Occultations Visible in Longitude +98° 0′, Latitude +31° 0′										
May 4	134 B.Scor	6.4	5 17.5	..	..	44	5 43.9	..	..	359
5	*W* Sgtr	4.7	12 30.1	..	..	146	12 59.7	..	..	195
6	183 B.Sgtr	6.2	10 29.1	—2.5	—0.1	97	11 50.0	—1.8	+0.5	236
22	4 Canc	6.2	2 35.7	—1.5	—0.3	68	3 20.4	+0.7	—2.8	342
28	*g* Virg	5.7	2 7.5	—1.9	—0.5	115	3 21.1	—1.2	—1.7	328
28	BD—8°3495	6.4	3 30.0	+0.3	—3.1	185	4 16.3	—3.3	+0.1	258
30	47 G.Libr	6.1	4 19.6	—1.3	—1.0	138	5 34.2	—2.2	—0.5	284
Occultations Visible in Longitude +120° 0′, Latitude +36° 0′										
May 3	*A* Scor	4.8	12 42.7	—0.9	—0.6	71	13 40.0	—1.0	—2.0	308
5	*W* Sgtr	4.7	11 29.0	—2.2	—0.5	107	12 45.5	—1.7	—0.1	247
6	183 B.Sgtr	6.2	9 45.2	—1.7	+0.8	93	11 6.2	—2.1	+0.6	259
21	47 Gemi	5.6	4 30.0	+0.3	—1.3	107	5 23.2	+0.5	—1.2	285
26	89 Leon	5.8	7 25.6	—0.4	—2.0	140	8 24.3	—0.3	—1.6	287
28	*g* Virg	5.7	1 39.7	—0.6	—0.7	142	2 46.2	—1.4	—0.1	295
30	47 G.Libr	6.1	4 2.6	+0.5	—2.0	176	4 43.2	—2.6	+1.7	248

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

THE PENNSYLVANIA FIREBALL OF OCTOBER 26, 1949, A.M.S. NO. 2320

PART I

BY CLAUDE H. SMITH

An Associated Press dispatch from Buffalo, N. Y., on October 27, 1949, reported that several people had seen a brilliant light in the sky during the evening of October 26, 1949. A little story was printed in our local newspaper and given over the air from our local radio station to determine if the report was worth investigating and, if so, the general direction to concentrate on for reports.

This is a good illustration of why all reports of unusual lights in the heavens should be followed up, for the first reports were most promising and showed that something unusual had taken place to the south and southwest of this section of the state. A letter was then sent immediately to 18 newspapers in western New York and Pennsylvania with an appeal for eye-witnesses to write. Altogether about 120 reports were received including a few that were originally sent to the headquarters of the American Meteor Society and had been resent here. Each was sent a copy of *A.M.S. Bulletin No. 16.* Those that sounded most promising were sent a personal letter. Of this number 63 returned the *Bulletin.* As 16 could be assigned to other fireballs, 47 were used to compute the path of what apparently was the most spectacular one.

The most interesting fact discovered was that several large meteors or fireballs were seen on the night of October 26 and that others were also seen around this date. A young girl of sixteen who was out playing halloween pranks on her neighbors that night saw 4 from 7:00 o'clock to 9:00 o'clock. A few other people reported seeing two on this date. If a check of newspaper files all over the country were made it should disclose the interesting observation that there was a concentration of fireballs during the latter part of October, 1949, that reached its peak on October 26.

The appearance of so many fireballs during the same evening complicated the task of grouping the different ones. People are as a rule vague about exact time and this did not help matters any. The fireball computed was so unusual, because its path was a decided arc and because of the bursts or explosions reported, that most reports between 8:30 o'clock and 9:30 o'clock referred to the same object.

This splendid fireball appeared at 9:00 P.M., E.S.T. The time is accurate within 2 or 3 minutes. The reports as to size vary widely, running from 3 times Venus to twice the size of the Moon. An average of all reports gives an apparent diameter of at least three-quarters the size of the full Moon. It must have been a very spectacular object for several colors are given. Fifty per cent mentioned blue, either alone or in combination with another color. A good summary would be a quotation from one eye-witness' report: "A bright beautiful blue ball."

It began over a point just south of Tioga, Pa., at an altitude of 61 miles. This is an average of all reports used, and if nine or ten of the seemingly best reports alone are averaged the results would still be the same. We can safely assume that this is a fairly accurate estimate of the altitude when it first became visible. The ending point was much more complicated due to the fact that there were at least two explosions. What eye-witnesses saw depended to a great extent on their point of observation. Many saw it from moving vehicles, city streets, or thru the windows of their homes and were hampered by artificial light. Those who were out in the open away from city lights had the best chance to see it and to them it was an awe-inspiring sight. The following is a summary taking all the best observations into account. These include observers near the end point and those who saw it from a distance.

It began as a large bluish ball of fire closely followed by several smaller balls or fragments of different colors. There was no long lasting train and any observed seemed to be composed of sparks that disappeared at once. One observer said the large ball was revolving but not enough is known from others to be sure of this fact. Such might be the case for it was not following a straight path but arcing toward the earth, suggesting a highly irregular solid nucleus. It traveled in this manner, increasing in brightness and size, 95 ground miles to a point a few miles north of Cornplanter, Pa., where it exploded in a great flare of light

at an altitude of about 21 miles. Numerous red sparks flew from the blaze of light and disappeared as they dropped toward the earth. At this point a smaller ball emerged from the blaze and continued on. The smaller ball seemed to have a deeper slope and first impressions were that it veered slightly to the north but this is probably not the case. The deeper slope was apparently the cause of the decided arc near the end-point witnessed by many from a distance. The smaller ball traveled about 17 miles farther to a point a mile or two east of Sugar Grove, Pa., and nearly on the New York State line. At this point it exploded again at an altitude of 14 miles or less and separated into two pieces that traveled seven miles farther before disappearing in the darkness. The ground point using a straight path would be near Wattsburg, Pa., but because of the deeper slope the ground point could very well be a few miles west of Bear Lake, Pa.

Meteorites very likely were dropped by this fireball and the author would predict that they might have reached the ground somewhere between Bear Lake and where Highway 426 crosses the state line, a distance of nearly ten miles and extending a few miles on each side of the state line. Predicting a "strewn-field" of such a small area, namely 10 by 6 miles, especially when based entirely on "arm-chair" sleuthing and not on accurate field instrument measurements, might seem to be a doubtful procedure and such might very well be the case. Due to the complexity of the explosions near the ending point it would be much safer to predict a "strewn-field" area of 20 by 10 miles using the first area as a center and expanding out correspondingly on all sides. In figuring this field great importance was placed on the fact that so many witnesses saw it descend in an arc. This should cut short the ground point even if a greater height were assigned to the first explosion. The two fragments that broke off at the second explosion and disappeared in the darkness might very well have reached the ground at the farthest point in this field. As either should have made a sizable hole in the ground an attempt will be made in the spring to get in touch with as many residents of this area as possible to try and recover some portion of this fall. The accompanying map shows the probable area where meteorites might be recovered.

The slope and the length of the path are hard to figure because the fireball traveled in an arc. Using a straight path the slope would be about 23° and about 130 miles from the beginning to the ending points. The arc of the path would point to a slightly longer path and a deeper slope near the end and undoubtedly such is the case. The estimates of the time the fireball was visible is in much better agreement. Dropping only 3 of from 15 to 70 seconds as wholly improbable, the remaining 27 reports that furnished this information give estimates ranging from less than a second to 5 seconds. This would give a velocity of about 43 miles per second. This is doubtless much too high because as usual many witnesses saw only a part of the entire path. Almost one-half of the reports give 4 or 5 seconds and probably saw a greater portion of the path. Using 5 seconds the velocity would be about 26 miles per second. This would appear as a closer average speed. It must have had a very respectable initial velocity that was reduced considerably by its apparent irregular shape, by the denser air at the low altitude it attained, and most of all by the explosions themselves.

Nine observers reported hearing the explosion or sounds of its passage. Five of these were close to the ending point. At Russell, Pa., a loud explosion was heard overhead, no time given. At Warren, Pa., a low zoom was heard 15 or 20 seconds after it disappeared. At Frewsburg, N. Y., a noise was heard in the sky and on looking up the light was seen. At Jamestown, N. Y., one observer heard a crackling or sputtering sound at the same time the light was visible while an-

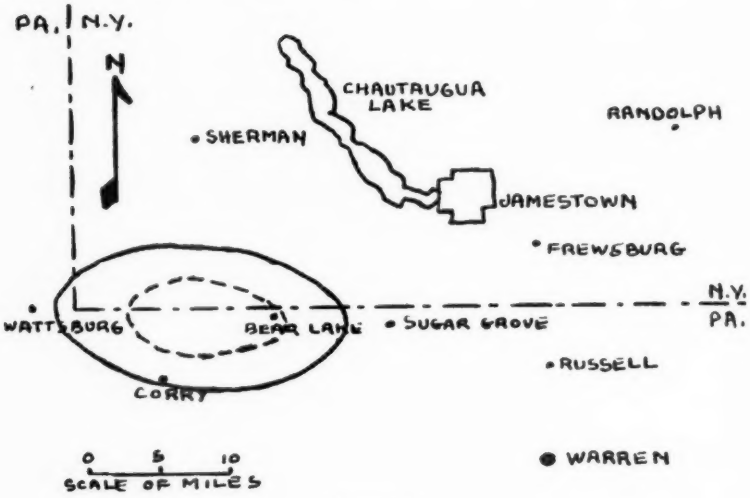

FIGURE 1

Area where meteorites might have fallen from the fireball of October 26, 1949, is shown by solid oval. Best chances for recovery should be in dashed oval.

other observer heard sound in 2 seconds and also heard an explosion although no time was given.

Four other observers heard sound from a distance. At Buffalo, N. Y., a low Sh-Sh-Sh was heard at the same time the light was seen. At Wyalusing, Pa., an explosion was heard right away and sounds very shortly afterwards. At DuBois, Pa., one observer reported sounds in 1 second while another heard an explosion right then and sounds in from 3 to 5 minutes.

As the Moon was near the horizon at the time of its appearance and as there were only a few clouds over most of the territory it was visible from, it must have been a most awesome and beautiful spectacle to those who had the good fortune to see it.

Not every observer will be mentioned by name because the large number makes this impracticable. Our Society is grateful to all who took the trouble to help by writing letters and filling out *Bulletin No. 16*, many with accompanying diagrams and notes. The work of the daily press in printing the initial article is greatly appreciated for without its help it would have been impossible to get in touch with eye-witnesses in the first place.

PART II

BY C. P. OLIVIER

As C. H. Smith has had considerable experience in working on fireball heights the projected path derived by him is taken by me as correct, also the derived heights of beginning point, explosion points, etc., and a diagram showing the path in the vertical plane. It should then be easy to compute the orbit but for a peculiarity of the latter drawing clearly showing the path slightly concave to the ground. As Smith made a close study of the reports we must assume that

this curvature is true. Then to derive the radiant there are two possibilities: first taking the curvature as correct we must draw a tangent to the upper part of the curve and, projecting this above the path, use the height this is above first explosion point X_1 plus height of X_1 from the ground as our second height (actually $12 + 36 = 48$ km); or, second, taking the actual height of X_1 and computing the path as a straight line from X_1 to B′, the beginning point on both hypotheses. The azimuth of the radiant is unchanged, but the first procedure gives an uncorrected altitude of 18° 47′, the second of 22° 38′; in each case a curvature correction of 42′ must be added. Though it is my opinion that the first procedure, which allows for curving of the path, is much more nearly correct, I was curious to see how much difference in the elements would be made by also using the second. I have therefore computed both, assuming parabolic heliocentric velocity, and the results will be shown below. For uniformity with our usual procedure, I have turned the values given by Smith in Part I and on his diagrams into kilometers and tabulated the data as follows:

A.M.S. No. 2320

Date		1949 Oct. 27.09 G.C.T. = Oct. 26.59 G.M.T.	
Sidereal time at first explosion point X		350°.1	
Began over B		$\lambda = 77° 05'$, $\phi = 41° 50'$ at 100 km	
First explosion over X		$\lambda = 78° 56'$, $\phi = 41° 57'$ at 36 km	
Last explosion over Y		$\lambda = 79° 20'$, $\phi = 41° 59'$ at 17 km	
Probable end-point over E		$\lambda = 79° 27'$, $\phi = 41° 59'$ at 11 km	
Projected path BX		155 km	
Projected path BY		183 km	
Projected path BE		208 km	
Path length B′X′		164 km	
Path length B′E′		221 km	
(In last two cases path considered as straight)			
Duration		5 ± sec	
Observed velocity (unc.)		44 ± km/sec	
Radiant (uncorrected for Δz)		a = 274°, h = 19° 29′	a = 274°, h = 23° 20′
Zenith correction parabolic		— 1° 7′	— 1° 9′
Radiant corrected		a = 274°, h = 18° 22′	a = 274°, h = 22° 11′
		$\alpha = 63.7$, $\delta = -9.3$	$\alpha = 60°.8$, $\delta = -11.8$
Orbital elements:	i	60°	; 40°
	☊	33°	; 33°
	π	182°	; 183°
	q	0.071 A.U.	; 0.068 A.U.

It will be seen that the only one of the parabolic elements which differs appreciably is the inclination i; all the other elements remain almost unaffected. The reason for this is that the position of the Earth was rather near the true radiant point(s), hence a very few degrees in the sides of the right triangles whose bases were l-E and perpendicular sides b (l being the longitude of the true radiant and b its latitude, and E the longitude of the Earth) make a very large difference in angle i, which is opposite b. As usual parabolic heliocentric velocity is assumed as the observed velocity is subject to such enormous accidental errors, due to well-known causes, that usually it has little value.

It is hoped that a solution can be found for another bright fireball seen at 10:02, E.S.T., on this same night, the reports on which were also mostly gathered by Smith, to whom all the credit for the labor of collecting the data for these fireballs and computing the atmospheric path in Part I goes.

Flower Observatory Reprint No. 77, containing Meteor Notes for 1949, has been received and already sent to all members whose 1950 dues have been paid.

Others will receive it when their dues reach us. It is our intention to drastically revise our membership list in the near future, dropping names of persons who do no observing and also are delinquent in their dues. We wish to prepare the annual report within a month. Therefore if anyone has not yet reported work done in 1949, please do so at once so that proper acknowledgment can be given.

Flower Observatory of the University of Pennsylvania, Upper Darby, Pa.
1950 February 22.

Contributions of The Meteoritical Society

(Known Formerly as The Society for Research on Meteorites)

Edited by FREDERICK C. LEONARD

Department of Astronomy, University of California, Los Angeles 24

The Effect of Cosmic Rays on Meteorites

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Communicated by Lincoln La Paz

ABSTRACT

An investigation has been made into the effect upon meteorites in space of the primary rays in the exceedingly strong cosmic radiation that falls upon these bodies before they penetrate the Earth's atmosphere. Specimens of meteorites with terrestrial ages (*i.e.*, intervals since time of fall) ranging from 9 months to 457 years were studied by means of the nuclear-emulsion-plate technique.

The oldest meteorite studied (Ensisheim, Alsace, France) was found to be inactive, and the next oldest (Pitts, Georgia) was only very slightly active. On the other hand, the relatively young Walters, Oklahoma, meteorite showed considerable activity, and a metallic inclusion and one piece of crust from the very recent Norton-Furnas Counties, Kansas-Nebraska, achondritic fall of 1948 February 18 were very active indeed. Another piece of Norton crust showed only slight activity, and two other fragments of this achondrite were inactive.

Examination of the nuclear "stars" recorded on the emulsion plates shows that the activity observed in the specimens studied is an induced one and cannot be attributed to the low content of natural radioactive elements present in the meteorites. Tentative explanations of this induced activity are advanced in the paper.

In recent years physicists and meteoriticists have been more and more interested in the investigation of cosmic rays. These rays have been measured at the surface of the Earth, under bodies of water, and at increasingly higher altitudes above sea-level. It has been found that only a comparatively small amount of the primary radiation penetrates the whole atmosphere, but that the primaries on hitting the air molecules transmute the atoms by their violent impact and that what we receive at the bottom of the atmosphere are the disintegration products. A great number of particles have been found, such as positive and negative electrons, protons, deuterons, and mesons. The investigation now proceeds towards finding out more about the energy and the character of the primary radiation. Instruments have been taken up in airplanes and in unmanned balloons; and even

rockets, when ascending to more than 100 miles, have carried recording instruments to measure the primary rays. These rockets reach heights where it is assumed that primaries form by far the largest part of the radiation; but, since the rockets remain at the highest elevations for only a short time, they can record only a few particles. We are thus better informed about the secondary or tertiary radiation than about the primary. It therefore seems interesting to study the effect of the primary rays in a different way. Exceedingly strong cosmic radiation will fall upon meteorites while they are in space. The atoms in them will undergo transmutations, and, if induced radioactive atoms are formed, the decay of these atoms may be observed for some time after the meteorites arrive on the Earth.

That iron meteorites emit α-particles and thus contain helium has been known for a long time.[1] The helium content has been measured thoroly, and the age of the meteorites since their solidification has been computed, on the assumption that traces of uranium or thorium are responsible for the emission of the rays. More recently, Bauer[2] has suggested that these meteorites became radioactive under the impact of cosmic radiation. If this suggestion is correct, certain differences should be evident: Meteorites of all kinds, not merely iron ones, should be active, and, since induced radioactivity has a much shorter life than has uranium or thorium, mixed with their daughter elements, the activity should gradually cease after a few years. In order to study this question, several meteorites, differing widely in age and class, were chosen. They were:

TABLE 1

Name	*Class*	*Date of Fall*	*Character of Test Specimens*
Ensisheim, Alsace, France[3]	Chy, kb	1492 Nov. 16	Stone with 3% iron.
Pitts, Georgia	O, n	1921 Apr. 20	Iron.
Walters, Oklahoma	C, v	1946 July 28	Slice thru the whole stone, not yet analyzed.
Norton County, Kansas[4]	A_2no	1948 Feb. 18	Achondrite, analysis available, but not yet published. Several pieces of the stony part with and without crust; one nickel-iron inclusion.

The method used in investigating the forenamed specimens was the photographic one: When nuclear-track plates are subject to the impact of very energetic nuclear particles, atoms—mostly in the emulsion, but in some cases in the underlying glass—are hit in head-on collisions and explode. The fragments, if charged, cause tracks while flying thru the emulsion. The result of such an explosion, a so-called "star," is shown in Fig. 1. From the spacing of the grains in the emulsion, it can be seen whether the "prongs" of the "star" are caused by α-particles, protons, deuterons, or heavier particles. Electrons, unless of very low energy, do not show up, and neutrons, since they are not charged, do not register. The incident particle must have an energy of about 100 Mev in order to cause an explosion.[5]

Eastman Kodak NTB plates, 1 × 3 inches, were placed close to each specimen and kept there for from 1 to 4 weeks. After development, when examined with a microscope, the plates showed the numbers of "stars" given in Table 2. (Only the best plate of each set was measured completely.)

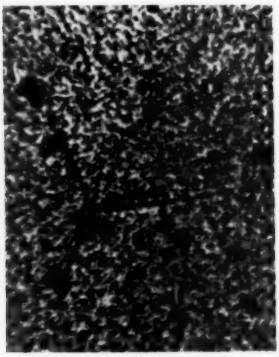

FIG. 1
A "STAR" CAUSED BY THE EXPLOSION OF ATOMS IN AN EMULSION PLATE, AFTER BEING HIT BY ENERGETIC NUCLEAR PARTICLES, × 600

TABLE 2

Name	*Time after Fall*	*Exposure*	*"Stars" with n "Prongs"* $n=3$	$n=4$	$n=5$	$n>5$
Ensisheim	457 years	1-3 weeks	0	0	0	0
Pitts	28.5 years	14 days	0	1	1	0
Walters	30 months	20 days	12	5	7	0
Norton County						
Fragment from						
Interior	9 months	20 days	0	0	0	0
Crust (*a*)	9 months	20 days	19	11	2	0
Crust (*b*)	18 months	20 days	3	1	1	0
Crust (*c*)	18 months	21 days	0	0	0	0
Metallic Inclusion	22 months	30 days	30	21	5	3

As was to be expected, the activity of Ensisheim has entirely ceased. (Short α-tracks, present, were not recorded.) Pitts is still slightly active, whereas Walters shows considerable activity. One piece of the stony part of Norton County is very active, another slightly so, and two others not at all, whereas the metallic inclusion from this achondrite produced more "stars" than did all the other specimens combined.

Table 2 shows definitely, by the presence of "stars," that the activity in the meteorites is an induced one and cannot be due to traces of natural radioactive elements. The most energetic α-particle coming from an element of the uranium or thorium family has an energy of 8.8 Mev (Th C'), and that is far less than is necessary for "star" production (~ 100 Mev).

Some conclusions about the nature of the induced radioactive elements that produce the "stars" may be drawn from column 2 of Table 2. Atoms with induced radioactivity have, as a rule, a short half-life, of the order of seconds, minutes, or days. There are, however, among the more common elements, two with a comparatively long half-life. These are Na^{22} (3 years) and Fe^{55} (4 years). Both have been produced in the laboratory by the following reactions:

$$\text{I}^{6}: \quad {}_{12}Mg^{24} + {}_{1}H^{2} = {}_{2}He^{4} + {}_{11}Na^{22}$$
$$\text{II}^{7}: \quad {}_{26}Fe^{56} + {}_{0}n^{1} = {}_{2}{}_{0}n^{1} + {}_{26}Fe^{55}; \textit{ or}$$
$$\text{III}^{7}: \quad {}_{26}Fe^{54} + {}_{1}H^{2} = {}_{1}H^{1} + {}_{26}Fe^{55}$$

The element $_{11}Na^{22}$, when decaying, emits a positive electron and a γ-ray, and

changes to $_{10}Na^{22}$; $_{26}Fe^{55}$ captures an electron and emits a γ-ray of an energy of 78 Mev.[8]

A tentative explanation may be presented for the activity of the meteorites after 2, 3, and even 28 years. If the meteorite contains iron, either of the last two reactions may have taken place. The stable atom Fe^{56}, bombarded by a neutron, emits a proton and leaves the radioactive Fe^{55}; or the isotope Fe^{54}, bombarded by a deuteron, emits a proton and changes to Fe^{55}. Fe^{54}, tho rarer than Fe^{56}, is present to the extent of 6% in ordinary iron.

Complete analyses of the Norton County achondrite will appear in a paper soon to be published by Drs. Lincoln La Paz and Carl W. Beck. The data given here were received in a personal communication from the former author. The metallic inclusions, scattered thruout the mass, contain 90.63% Fe, 6.35% Ni, 1% Al, and traces of other elements. The thin inclusion investigated in this paper has a length of 17 mm. and a breadth of 11 mm.; hence, it does not cover the photographic plate so completely as do the other pieces. More than 90% of the stony part of the meteorite is a silicate of magnesium, and less than 1% is iron. The reaction given in equation (I), *ante*, may therefore have taken place. Further investigation will be necessary in order to explain why some parts of the stony portion of Norton County are very active whereas others are quite inactive.

It is interesting to note that the ratio of "stars" with more than 3 "prongs" to the total number is greater for the heavy-metal constituent of the meteorites than for the lighter constituents. Tho the number of "prongs" does not allow any definite conclusion to be drawn about the energy of the incident ray, as a rule it may be said that the greater the energy of the "star"-producing particle, the greater the number of "prongs."

It would be interesting to study a meteorite immediately after its fall to Earth. It may be that other induced radioactive elements with half-lives of the order of a few days would be found.

I am greatly indebted to Mr. E. P. Henderson, Associate Curator, United States National Museum, Washington, D. C., for the loan of the Ensisheim, Pitts, and Walters meteorites, and to Dr. Lincoln La Paz, Director, Institute of Meteoritics, University of New Mexico, Albuquerque, for the loan of several specimens of the Norton County achondrite, and for other assistance. A helpful discussion of this paper by Dr. C. A. Bauer, of the Observatory of the University of Michigan, is gratefully acknowledged.

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New Chemical Analyses of the Canyon Diablo, Arizona, and Arispe, Sonora, Mexico, Siderites

JOHN DAVIS BUDDHUE

99 S. Raymond Avenue, Pasadena 1, California

It has long been a source of surprise to me that a meteoritic fall as well known and as abundant as Canyon Diablo, Arizona (ECN = +1110,350A; cl. = Ogg), is so poorly supplied with analytical data. The component minerals, with the exception of troilite, have been analyzed repeatedly, but of the 9 analyses of the metal as a whole, only 3 are complete, and 2 of these refer to shale-ball cores, thus leaving only 1 analysis of the normal meteorite.[1,2]

Some time ago I undertook to prepare a spherical specimen of Canyon Diablo. The attempt was successful; and I obtained, as a by-product, a considerable quantity of shavings. A sample of these was analyzed by Mr. F. G. Hawley, with the results shown in Table 1. I give also Whitfield's analysis (slightly abridged) for comparison. The nickel contents, especially Hawley's values, are surprisingly high for those of a coarsest octahedrite (Ogg), but to a certain extent they confirm each other.

TABLE 1

	Canyon Diablo		*Arispe*
	Whitfield	Hawley	Hawley
Fe	89.17%	90.43%	92.46%
Ni	7.33	8.54	6.80
Co	0.51	0.49	0.45
Cu	0.01	0.04	0.06
Cr	.....	0.02	0.02
Mn	Nil	.....	0.001
P	0.26	0.34	0.314
S	0.01	0.13	0.020
C	0.10	Low	0.014
SiO_2 or Si	Trace	0.08	0.030
Misc.	2.65	.....	.....
Total	100.04%	100.07%	100.169%

At another time I commented to Mr. Hawley that there was no satisfactory analysis of the Arispe (or Arizpe*), Sonora, Mexico, siderites (ECN = +1100,302; cl. = Ogg). He replied that he had made an analysis some years before, but had never published it. The results of his analysis are given, with his permission, in Table 1. This analysis applies specifically to a 68.5-lb. mass found in 1936 by Rafael Carillo in the same locality as previous finds. Whitfield[3] had previously determined the percentages of iron (92.27%) and nickel (7.04%), but nothing else.

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The J. Lawrence Smith Medal of the National Academy of Sciences

The recent award of the J. Lawrence Smith Medal of the National Academy

*As Mr. Hawley and others have remarked, the spelling *Arizpe* may be the correct one, altho *Arispe* is the spelling usually found in meteoritical catalogs. In M. H. Hey's catalog (1940), *Arizpe* is listed as an "additional synonym."

of Sciences to Dr. Fred L. Whipple was noted in *C.M.S., P.A.*, **58**, 40, Jan., 1950. In her "News Notes" in *Sky and Telescope*, **9**, 32, Dec., 1949, Dr. Dorrit Hoffleit writes: "The fund for this medal was established in 1884 to encourage research on meteors, and in the past it has been awarded only three times: in 1888 to H. A. Newton for investigations on the origin of meteors; in 1922 to G. P. Merrill for work on the character of meteorites; in 1945 to Stuart H. Perry for studies on the metallography of meteoric iron."

Dr. Perry, who, like Dr. Whipple, is a Councilor of the Meteoritical Society, is the author of that classical treatise entitled "The Metallography of Meteoric Iron" (*U. S. Nat. Mus. Bull. 184*, vii + 206 pp., 1944), for the publication of which he was presented with the Smith Medal.

Committee Appointment

As of date 1949 December 28, Dr. John A. Russell of the University of Southern California, Los Angeles, California, has been appointed by President King to serve as a member of the Committee on a General Catalog of Meteoritic Falls (*v. C.M.S.*, **4**, 237; *P.A.*, **57**, 517-18, 1949). An informal meeting of 3 members of this committee (Drs. LaPaz, Leonard, and Russell) was held at the University of Arizona, Tucson, in the course of the recent meeting there of the American Astronomical Society (1949 December 28-31).

President of the Society: ARTHUR S. KING, 925 Topeka Street, Pasadena 6, California

Secretary of the Society: JOHN A. RUSSELL, Department of Astronomy, University of Southern California, Los Angeles 7, California

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By MARGARET W. MAYALL, Recorder

Recent Publications Received: In a group of reprints, Sammlung von Abdrucken, Heft 8, from the Sternwarte der Deutschen Akademie der Wissenschaften zu Berlin, in Sonneberg, there are two by Paul Ahnert. One of them gives his observed dates of maxima and minima from 1945-47, for 34 long-period variables. The second paper, reprinted from *Astronomische Nachrichten*, Vol. 276, No. 3, contains studies of the variations of SS Geminorum (060222), S Vulpeculae (194427), and Z Leonis (094627), all members of that interesting group of variables with periods between 50 and 100 days. SS Geminorum is an RV Tauri-type variable with a mean period of 89.1414 days, and a variable amplitude. Its mean range is from 8.4 to 9.3 visual, and 9.3 to 10.5 photographic. S Vulpeculae has a light curve similar to a Cepheid curve, but has a period which varies from 67.37 days to 68.18 days. Its mean visual range is from 8.68 to 9.58 and its photographic from 10.31 to 11.60. Between 1899 and 1933, Z Leonis had a Cepheid-type light curve and a constant period of 26.85 days. Since 1933 it has become more irregular, and the mean period varies from 55.17 days to 56.85 days. Before 1933 the mean visual range was from 8.98 to 9.52; since 1933, it is smaller, from 9.00 to 9.30.

Another reprint from *Astronomische Nachrichten*, Vol. 276, No. 5/6, is a paper by H.-U. Sandig of Bamberg, Germany, on the period and light curve of Mira Ceti. He has compiled material on the observed dates of maxima from 1596 to 1947, covering 386 epochs.

In *Circular No. 42* from the Variable Star Section of the Royal Astronomical Society of New Zealand, Mr. Bateson gives a very thorough discussion of the suspected variation of the naked-eye star, Epsilon Crucis, 121860. He had available a total of 2,174 observations, covering the period from 1930 to 1947, made by 19 members of the Variable Star Section with naked-eye or binoculars. At first glance, there appeared to be a variation from 3.47 to 4.07 in the 10-day means. Mr. Bateson determined the systematic deviations for each of the observers, and after applying the corrections, he came to the conclusion that Epsilon Crucis may possibly vary from 3.4 to 3.8 in approximately 70 days. Some more precise method of observation will be necessary to prove the reality of this small variation.

Mr. L. T. Shen of Nanking, China, has sent in a report of 216 observations of 56 stars made between July 20 and December 31, 1949. He writes that the Institute of Astronomy of Academia Sinica, under the directorship of Dr. Y. C. Chang, returned from Shanghai to Nanking, its original site, last September, and he has been appointed as Assistant at the Purple Mountain Observatory. On very clear nights he observes stars down to 14.5 or 14.6 magnitude with the observatory's 8-inch refractor.

A.A.V.S.O. Spring Meeting: The 39th Annual Spring Meeting of the A.A.V.S.O. is to be held at State College, Pennsylvania, the weekend of May 5 and 6. On Friday evening, May 5, Dr. Yeagley, Director of the Observatories, will talk on "Terrestrial and Extra-Terrestrial Influences on Bird Navigation." Sessions for business and presentation of papers, and the Society luncheon, will be held on Saturday.

SS Aurigae, 060547. A rise in brightness of SS Aurigae to 11.3 on February 21 was reported by Calvin Toche. The two previous maxima in October and December, 1949, were well observed.

RR Telescopii, 195656. The interesting southern variable, RR Telescopii, seems to be increasing in brightness again. It was a little fainter than 8th magnitude from JD 2,433,200 to 3,260, but R. P. de Kock observes a rise from 8.0 to 7.5 between 3,290 and 3,309. The star has been fairly constant around the 7th magnitude from 1945 until August, 1949, and before that it was fainter than 12, and seemed to vary with a period of about 386 days. (See the light curve in the Variable Star Notes, POPULAR ASTRONOMY, Dec., 1948.)

Nova Lacertae 1950, 224552. Paul Ahnert, of Sonneberg, Germany, has sent in a pre-discovery observation of Nova Lacertae. He found the nova to be magnitude 6.6 on a photographic plate taken on January 20, 3 days before Bertaud's discovery plate. It was more than half a magnitude fainter than Bertaud's observation, and was evidently on the way up to maximum. The nova is fading very slowly, and for the last 2½ weeks, from JD 2,433,335 to 3,353 it has hovered between 8 and 8½ magnitude.

Observations received during February, 1950: A total of 3,153 observations was received during the month from 56 observers, as follows:

Observer	No. Var.	No. Ests.	Observer	No. Var.	No. Ests.
Adams	27	61	Kanda	4	21
Ahnert	26	136	Kelly	13	13
Ancarani	6	6	Knowles	18	29
Armfield, E.	1	1	de Kock	99	418
Armfield, L.	9	40	Lacchini	59	76
Bogard	63	104	Lankford	11	35
Cain	1	1	Leutenegger	12	33
Chandra	132	192	Lowder	1	2
Charles	16	16	Meyer	5	5
Cilley	20	61	Naef	1	4
Cooke	1	1	Oravec	61	146
Cragg	1	1	Pearcy	109	119
Dafter	6	27	Peltier	153	195
Darling	12	19	Penhallow	30	41
Diedrich, DeL.	2	10	Peter	4	11
Diedrich, G.	3	10	Pierson	99	108
Dillon	4	7	Renner	98	98
Drakakis	10	18	Rosebrugh	14	63
Estremadoyro, V. A.	6	9	Shen	56	216
Farnsworth	2	2	Snow	1	1
Fernald	130	200	Stevens	15	15
Flather	9	16	Tifft	1	1
Ford	7	8	Upton	7	14
Galbraith	17	55	Venter	15	22
Greenley	64	105	Welker	1	5
Hamilton	1	6	Yamada	23	48
Hartmann	138	154	Yoshihara	25	146
Holloway	1	3	—		—
Jackson	1	1	56	totals	3,153

Nova Search. Reports on the Nova Search Program were received during February from 7 observers on areas as follows:

Adams: 16, 17, 33, 34.
Diedrich, DeL.: 94.
Diedrich, G.: 56.
Drakakis: 69, 70, 81, 82, 92, 101, 102, 110, 121, 122.
Rosebrugh: Dome, 1, 34.
Smith, F. W.: 3, 4.
Venter: 124, 125, 126, 135, 136, 137, 149, 150, 151, 161, 162, 163, 164, 165, 166.

March 15, 1950.

Comet Notes

By DANIEL L. HARRIS III

Comet activity is very slow at this time, no new comets having been discovered this year. In the March issue ephemerides were given for Comet d'Arrest and for Comet Schwassmann-Wachmann (1), 1925 II extending through April. Through an oversight on the writer's part, no ephemeris was given for Comet Johnson (1949*a*) although the object should be visible in small telescopes. The predicted positions for April and May are given below with the magnitudes based on the r^{-4} law.

EPHEMERIS OF COMET JOHNSON (1949*a*)

1950 U.T.	R.A. h m	Dec. ° ′	Mag.
April 5.0	12 19.4	+64 11	11.3
13.0	11 33.6	65 36	11.4
21.0	10 52.5	65 45	11.6
29.0	10 19.5	65 04	11.8
May 7.0	9 55.1	63 57	12.0
15.0	9 38.0	62 39	12.2
23.0	9 26.5	61 20	12.3
31.0	9 19.4	60 06	12.5
June 8.0	9 15.3	58 58	12.7

The above ephemeris is by Dr. Jorge Bobone of the Cordoba Observatory and represents the latest observations quite well.

(News release from the California Institute of Technology.)

General Notes

The Rittenhouse Astronomical Society, of Philadelphia, held its monthly meeting on March 10 in the Randal Morgan Physics Laboratory, University of Pennsylvania. The speaker was Dr. Lyman Spitzer, Jr., Director of Princeton University Observatory, on the topic "The Formation of Stars."

Dr. Alfred H. Joy Receives Bruce Gold Medal

Dr. Alfred H. Joy, Research Associate at the California Institute of Technology and of the Carnegie Institution of Washington, and retired Mt. Wilson and Palomar Observatories astronomer, received the Catherine Wolfe Bruce Gold Medal for 1950 at a meeting of the Astronomical Society of the Pacific in San Francisco on March 17. The award is for distinguished service to astronomy. Dr. Joy is the 43rd astronomer to receive this award, the twentieth American astronomer and the sixth from the Mt. Wilson Observatory to be so honored. Other scientists from that observatory to receive this award include the late Dr. George Ellery Hale, Dr. Walter S. Adams, Dr. Edwin P. Hubble, Dr. F. H. Seares, and Dr. P. W. Merrill. Drs. Hubble and Merrill are still active members of the observatory staff.

The award was made to Dr. Joy in recognition of his outstanding work in the field of stellar spectroscopy and was presented by Dr. R. J. Trumpler of the University of California. Nominations for the award are made by six observatories throughout the world. They are the Harvard, Yerkes, and Lick Observatories in this country, the Cordoba Observatory in Argentina, the Stockholm Observatory in Sweden, and the Greenwich Observatory in England.

Dr. Joy has twice been president of the Astronomical Society of the Pacific. He was a member of the Mt. Wilson Observatory for 33 years and at the time of his retirement in October, 1948, was secretary of the observatory. He has remained active since his retirement and is currently teaching at Caltech as well as continuing his research studies. During his early years at Mt. Wilson he began working in the field of stellar spectroscopy and, during his more than 30 years of research, contributed greatly to our knowledge of stellar distances, classification and characteristics of variable stars, radial velocities, absorption of light in interstellar space, and the theory of galactic rotation.

(News release from the California Institute of Technology.)

Provisional Sunspot Numbers for February, 1950*

1	70	10	37	19	197
2	34	11	66	20	190
3	37	12	72	21	170
4	35	13	85	22	162
5	63	14	125	23	137
6	61	15	144	24	113
7	31	16	156	25	96
8	19	17	154	26	76
9	20	18	166	27	70
				28	72

Mean Value for February
R = 94.6

*From the Zürich Observatory, furnished by Mr. Neal J. Heines.

An Unusual Planetarium Installation

The first completely American-made major planetarium is destined to project the stars in a strange and romantic setting—the heart of a great underground cavern in the Ozarks of Missouri. The planetarium, to be installed in Great Spirit Cave near Waynesville, Mo., will be in operation later this year, it was announced by Spitz Laboratories, of Philadelphia, manufacturers of the instrument.

This unprecedented project is the result of the desire of a Missouri housewife to own an unusual piece of property. Mrs. Frank Thomas of Springfield, Mo., after visiting a cavern owned by a friend, told her husband she, too, would like to own one. Thomas, a geologist and mine owner, decided to humor her whim. He finally settled on vast Great Spirit Cave, which runs underground for some fifteen miles and which once was the home of prehistoric Indian tribes. It was Thomas who conceived the idea of placing a planetarium in one of the cave's largest underground chambers, the Cathedral Room. When he told others of his plan, they said it was impossible. First of all, even if he could obtain a large planetarium instrument, the complete installation would cost him at least a million dollars. Moreover, the Zeiss Optical Works of Jena, Germany, where all of the six major planetariums now in this country were made, was severely bombed during the war and was no longer making the star projectors. Although Thomas was determined to get what he wanted, he met nothing but frustration until at last he was referred to Armand N. Spitz, director of education at The Franklin Institute in Philadelphia and a lecturer at the Fels Planetarium there. Spitz, Thomas learned, had successfully introduced a small planetarium designed especially for classroom use in schools and colleges.

When asked if he could make a large planetarium, capable of presenting the same sort of celestial spectacles as the no longer available German instruments, Spitz replied that he had been working on the design of just such an instrument for a number of years, but that the developmental work was not yet completed. At Thomas' insistence, however, he speeded up his work on the problem with the result that the actual manufacturing of the first full-size planetarium instrument to be made in the United States is now under way. The large Spitz Planetarium, although working on different basic principles, will do just about everything the German-made instruments are capable of and, Spitz says, will have a number of unique features all its own.

The planetarium will project on the artificial sky of the planetarium chamber all the stars that can be seen from anywhere on earth. It will reproduce the com-

plex motions of the sun, moon, and planets, showing their positions at any time in the past, present, or future. Special auxiliary projectors will enable the planetarium to be used in demonstrating the parts played by the stars in navigation, the determination of time, and other studies. Others will show such things as comets, meteors, variable stars, and constellation figures.

Many United States communities have been anxious to have planetarium installations like those in New York, Philadelphia, Chicago, Pittsburgh, Los Angeles, and Chapel Hill, North Carolina. The high cost of the German instruments, even when they were available, kept them out of the range of all but these few. Now that an American-made planetarium is available—and at a cost only a fraction of the pre-war price of the German instrument—it is likely that such dreams will at last come true.

(News Release from Spitz Laboratories, 2000 Parkway, Philadelphia 3, Pa.)

Book Reviews

The Science of Chance, by Horace C. Levinson. (Rinehart & Company, New York, 1950, $2.00.)

Probability and statistics are playing an increasing role in astronomy, as in every other science. At the same time, the problem of the statistical training of scientists and the educated public remains only partially solved. One of the major difficulties is the lack of adequate, sound books suited to the needs of the many groups who need to learn more about the subject. The Science of Chance makes a real contribution in this field. It is not a text-book in the theory or techniques of mathematical statistics, but it will serve as a very helpful supplement to such texts or as an alternative to them for those who need merely a general idea of probability and statistics. It concentrates on the intuitive presentation of the meaning of chance, the exposure of fallacies, and the extensive illustration of probability ideas in the field of games of chance, science, and business. It is an entertaining and instructive book.

Carleton College, March 17, 1950. KENNETH MAY

Measuring our Universe, From the Inner Atom to Outer Space, by Oliver Justin Lee. (The Ronald Press Company, 15 E. 26th St., New York 10, N. Y. $3.00.)

The title of this book, and also the amplification of it in the subtitle, arrest the attention because of the comprehensiveness of the undertaking. The reader is thereby warned to be prepared to cope with distances enormously great as well as with distances infinitesimally small. In the fourteen chapters, 167 pages, the author brings the reader face to face with the basic facts as revealed by the present status of physical science. With the knowledge gained from this volume, one is in a position to read more intelligently the large amount of scientific writing which is currently issuing from the press.

Before the reader has finished the first chapter, which is given the intriguing title The Romance of Distances, he has caught the spirit and tenor of the book. Consider, for instance, the concluding paragraph of Chapter 1.

> "Distances, when known, are like keys which unlock many of the doors of the universe. The outside of these doors may be beautiful, but to open them and to see what lies beyond is the most satisfying experience of an intellectual life."

Throughout the book it is quite evident that the author has a lively imagination, a keen appreciation of the poetical, and an active sense of humor. This is shown even in the titles of the chapters, such as, The Magic of Light Waves, Yardstick of the Gods, Accuracy is Like the Flavor of Exotic Wines, Private Interviews with Stars.

In a brief review one cannot hope to mention the many fine features of the book. The reviewer in this case can testify to the genuine enjoyment and intellectual stimulus he derived from a reading of it. This is because he frequently came upon sentences and paragraphs which in his opinion eminently qualify as fine writing. For example, in comments concerning large telescopes one suddenly comes upon this:

> "In the last decade of the nineteenth century the faithful 40-inch Yerkes refractor began its long service. In the second decade of the twentieth century the magnificent 100-inch on Mount Wilson thrust its great shoulders up against the mysterious, far-flung citadels of the heavens. And finally, toward the end of 1947, the 200-inch giant was assembled at Palomar."

The book is heartily and confidently recommended as easy, yet entirely exact and dependable scientific reading. C.H.G.

Der Sternenhimmel, (1950), by Robert E. Naef. (Published by H. R. Sauerländer & Co., Aarau, Switzerland.)

The description of the above title informs the reader that the paper-bound pamphlet of one hundred pages is an astronomical year book for those interested in the stars and that it contains suggestions concerning observations to be made with the unaided eye, by means of field-glasses or telescope, for each day in the year, and that it is issued under the patronage of the Astronomical Society of Switzerland.

The details given in the pamphlet are far too numerous to be mentioned singly. Suffice it to say that an every page one finds information of great value to the student. A careful following of the items throughout the year would result in a fairly good comprehension of the fundamentals of the science of astronomy. The author deserves congratulations upon having included so much material in such little space. One, of course, must understand the German language to derive the greatest benefit from it. C.H.G.

Astronomical Records in the Russian Chronicles from 1000 to 1600 A.D., by A. N. Vyssotsky. (Meddelande från Lunds Astronomiska Observatorium, Series 2, Nr. 126. Lund, Sweden, 1949. 51 pp. + 1 map.)

The importance of this memoir is that it opens up a field in the history of astronomy which has hitherto been rather inaccessible to the western reader. The author, although his work is published in Sweden, is American, on the staff of the Leander McCormick Observatory at Charlottesville, Va. What he has done is to translate, with critical notes, a collection of astronomical excerpts from the medieval Russian annalists, originally published in 1916 by the Russian historian D. O. Sviatsky.

The records refer to eclipses of the sun and moon, to comets, meteors, aurorae, and sunspots. Unfortunately there are no allusions which can be attributed to novae or supernovae.

Perhaps the most interesting item is the description of the total eclipse of

the sun on May 1, 1185, as observed at Novgorod. The Lavrientievsky chronicle states that the sun "became like a crescent of the moon, from the horns of which a glow similar to that of red-hot charcoals was emanating." Vyssotsky suggests that this is an observation of solar prominences, but Edison Pettit of the Mt. Wilson Observatory, on reading this passage, points out: "(It) is a good description of the chromospheric light which shows, with good seeing, at the tips of the horns of the crescent when the eclipse is nearly total. . . I doubt that prominences would ordinarily be visible until within a few seconds of total phase. They are never recorded at annular eclipse."

During the total lunar eclipse of November 23, 1276, the moon is recorded to have totally disappeared. Here is apparently an addition to the short list of unusually dark eclipses, at which the moon became too faint to be visible to the unaided eye.

Other reports worthy of particular mention deal with observations of the Leonid shower on October 18, 1202, and October 24, 1533, and with naked-eye sunspots in 1365 and 1371.

JOSEPH ASHBROOK.

Yale University Observatory, New Haven, Conn.

Our Sun, by Donald H. Menzel. (The Blakiston Company, Philadelphia. 315 pages, $4.50.)

"Our Sun," the latest of the Harvard books on astronomy, is a profusely illustrated account of the present status of solar research, giving a general, comprehensive discussion of the sun and its importance to the inhabitants of the earth. Like the rest of this Harvard series, "Our Sun" is written for the layman, but it is sufficiently detailed to disqualify it as light reading. Dr. Menzel has not written a textbook, or a reference book, but has succeeded admirably in putting into simple language what we know, or would like to know, about the sun. The popular exposition of such a subject is necessarily difficult, since the probable explanation of many solar phenomena is far from elementary.

The first three chapters contain a short introductory description of the observable features of the solar surface together with some of the aspects of solar physics; light, radiation, and the methods of determining the physical dimensions of the sun. Chapters four through nine elaborate on the general description, giving detailed accounts of solar phenomena and their possible explanations as well as a description and explanation of the instruments of solar research now in use. The last three chapters are entitled "Atomic Energy and the Solar Interior," "Eclipses—Old and New," and "The Sun—and You!" The section on atomic energy which is a well-written résumé of elementary nuclear physics, also considers some applications of atomic theory to the problems of stellar energy. The chapter on eclipses, which discusses briefly the causes of solar eclipses and their value to the astronomer, gives a list of all the eclipses of the sun from 1900 to 2000 A.D., arranged by saros. In the final chapter, Dr. Menzel paints a truly alarming picture of the rapid exhaustion of our natural resources, but at the same time discusses some of the efforts which might be made to avert the apparently impending catastrophe. Finally, some of the direct effects of the sun on the earth are considered, among them, the aurorae, variable radio reception, and the weather.

All twelve chapters are abundantly illustrated with pertinent diagrams and photographs, which add a great deal to the book. For example, Chapter IX, "The Corona Mystery," contains a series of eleven excellent coronal photographs taken during eclipses at various times of the sunspot cycles, over a period of nearly

forty years. No amount of explanation in the text could picture so well to the reader the changes of the corona at different times in the sunspot cycle. Throughout the volume, reproductions of the photographs taken with the equipment of solar research give the reader an excellent idea of what the solar astronomer has to work with.

In general, this book gives an accurate picture of the sun. There remain, however, as in most scientific fields, many points upon which a good deal of controversy exists and the critical reader may feel that these points are presented in "Our Sun" a little too much as settled questions.

As in any first edition, several errors have been discovered, most of them trival such as a picture upside down or a misplaced legend. Although the reader will find small faults and points of disagreement throughout the book, anyone desiring a good, non-technical account of solar research, and a complete, readable description of observed solar phenomena will find "Our Sun" enjoyable and satisfying.

JAMES M. PARKER.

Mount Wilson and Palomar Observatories.

Publications Received.—The publishers of POPULAR ASTRONOMY hereby acknowledge receipt of the following named publications and express their great appreciation of the courtesy shown on the part of those who sent them.

Contributions from the Mount Wilson Observatory:

No. 754. "Identification of a Molecular Band at λ 3682 in the Spectra of Late-type Stars," by George H. Herbig.

No. 755. "The Wolf-Rayet Spectroscopic Binary HD 190918," by O .C. Wilson.

No. 756. "High-Dispersion Spectrograms of T Coronae Borealis," by Roscoe F. Sanford.

No. 757. "Radial Velocities of RR Lyrae from Coudé Spectrograms," by Roscoe F. Sanford.

No. 758. "Stars whose Spectra have Bright H and K Lines of Calcium," by Alfred H. Joy and Ralph E. Wilson.

No. 759. "Photographic Studies of Nebulae—VI. The Great Nebulous Region is Cygnus Photographed in Red Light," by John C. Duncan.

No. 769. "Observations of Interstellar H and K, Molecular Lines, and Radial Velocities in the Spectra of 300 O and B Stars," by Walter S. Adams.

Annual Report of the Director of Mount Wilson and Palomar Observatories for the year 1947-1948.

Harvard Reprints:

No. 322. "Superthermic Phenomena in Stellar Atmospheres—III. The Chromospheric Radiation Field," by Richard N. Thomas.

No. 323. "The Stark Effect of the Higher Balmer Lines in Stars of Spectral Types A and B," by Elsa van Dien.

No. 324. "An Upper Limit to the Electron Density near the Earth's Orbit," by Fred L. Whipple and Joseph L. Gossner.

No. 325. "Nonradial Oscillations of the Standard Model," by Zdeněk Kopal.

No. 326. "The Polar Axis Adjustment of Photographic Telescopes," by Fred L. Whipple.

Harvard Reprint Series II:

No. 31. "Photographic Meteor Phenomena and Theory," by Luigi G. Jacchia.

No. 32. "Atmospheric Density Profile and Gradients from Early Parts of Photographic Meteor Trails," by Luigi G. Jacchia.

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